ANATOMY OF THE PERIPHERAL NERVES

A. MELVILLE PATERSON

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THE ANATOMY
OF THE
PERIPHERAL NERVES

BY
A. MELVILLE PATERSON, M.D., F.R.C.S.
LIEUT.-COLONEL R.A.M.C.
ASSISTANT INSPECTOR OF SPECIAL MILITARY SURGICAL HOSPITALS
PROFESSOR OF ANATOMY IN THE UNIVERSITY OF LIVERPOOL
EXAMINER IN ANATOMY AT THE ROYAL COLLEGE OF SURGEONS OF ENGLAND
ETC.

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PREFACE

The surgery of the war has made necessary a much more detailed and precise knowledge of the anatomy of the peripheral nerves, particularly the nerves of the limbs, than the surgeon required in pre-war days.

The object of this book is to provide a brief account of the peripheral nerves for the use of students and surgeons, particularly for those engaged in military orthopædic work.

One has introduced an account of the cranial nerves and sympathetic for the sake of completeness, and because of the intimate relationship of the sympathetic with the peripheral nervous system.

I am much indebted to the editor and publishers of Cunningham's *Text Book of Anatomy* for the use of illustrations. The schemes giving the positions of origin of the branches of the limb-nerves have been compiled from a series of dissections made by my assistant, Mr. D. H. Richards. Caution is needed in regard to these. One cannot dogmatise with regard to the precise point of origin of any branch. The branch possesses individuality long before it separates from the parent trunk and may be incorporated with it for a shorter or longer distance in different cases. The nerve to the short head of the biceps flexor cruris is a good example. It usually springs from the outer border of the peroneal (external popliteal) portion of the great sciatic trunk in the upper part of the

thigh; but it may arise in common with the nerve of the gluteus maximus (inferior gluteal), or it may arise in the popliteal space, and after hooking round the last perforating artery, pass upwards to the muscle.

A. M. Paterson.

Liverpool,
December 1918

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CHAPTER I

THE ANATOMY OF THE PERIPHERAL NERVES

THE nervous system may be subdivided into three parts :

(*a*) Central nervous system—brain and spinal cord.

(*b*) Peripheral nervous system—cranial and spinal nerves and sympathetic.

(*c*) Sense organs.

The following account is limited to a description of the peripheral nervous system, including its morphology and development and its topographical and surgical anatomy.

A Peripheral Nerve.—A peripheral nerve, such as the ulnar or peroneal, consists essentially of a series of nerve filaments or axons, the elongated processes of nerve-cells, each with its own individual central and peripheral connections. Each axon appears to extend continuously, without subdivision or union with neighbouring axons, from its origin in a nerve cell to its termination in a muscle or organ of sense.

The axons are of two kinds, anatomically and physiologically. They are known respectively as efferent and afferent fibres—motor and sensory in function.

The spinal nerves in general, the sympathetic system,

and some cranial nerves, contain both afferent and efferent fibres. Some cranial nerves, however, consist of only afferent or efferent fibres.

Taking as an example a spinal nerve which contains both afferent and efferent axons, the nerve is formed by the union of two roots—one dorsal, ganglionic and afferent; the other ventral, non-ganglionic and efferent (Fig. 1A).

The two roots consist of collections of nerve fibres, associated with the dorso-lateral and ventro-lateral aspects of the spinal cord. On the dorsal root (in the intervertebral

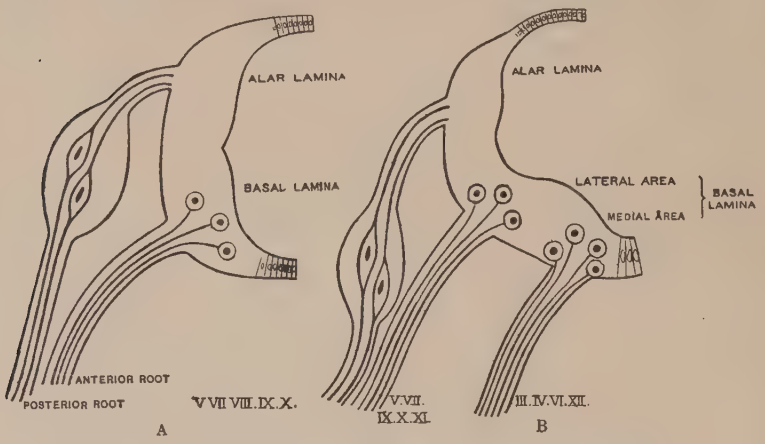


FIG. 1.—Morphology of the Spinal and Cranial Nerves.

foramen as a rule) is placed an oval swelling composed of nerve cells—the dorsal spinal ganglion. The nerve fibres beyond the ganglion unite with the ventral nerve root to form the " mixed spinal nerve " (Fig. 3).

The axons composing the nerve have very different connections, both peripherally and centrally.

Peripherally, an efferent axon is connected with a muscle fibre, voluntary or involuntary. An afferent axon is connected with a sense organ or the skin.

Centrally, an efferent axon, traced through the nerve, becomes a part of the ventral root, and is the process of a nerve cell in the ventral horn of the spinal cord (Fig. 1A).

These cells are multipolar ; one fibre is the efferent axon, which is prolonged outwards to become a component of the efferent, ventral nerve root. The other processes of the nerve cell are short and dendritic. They are associ-

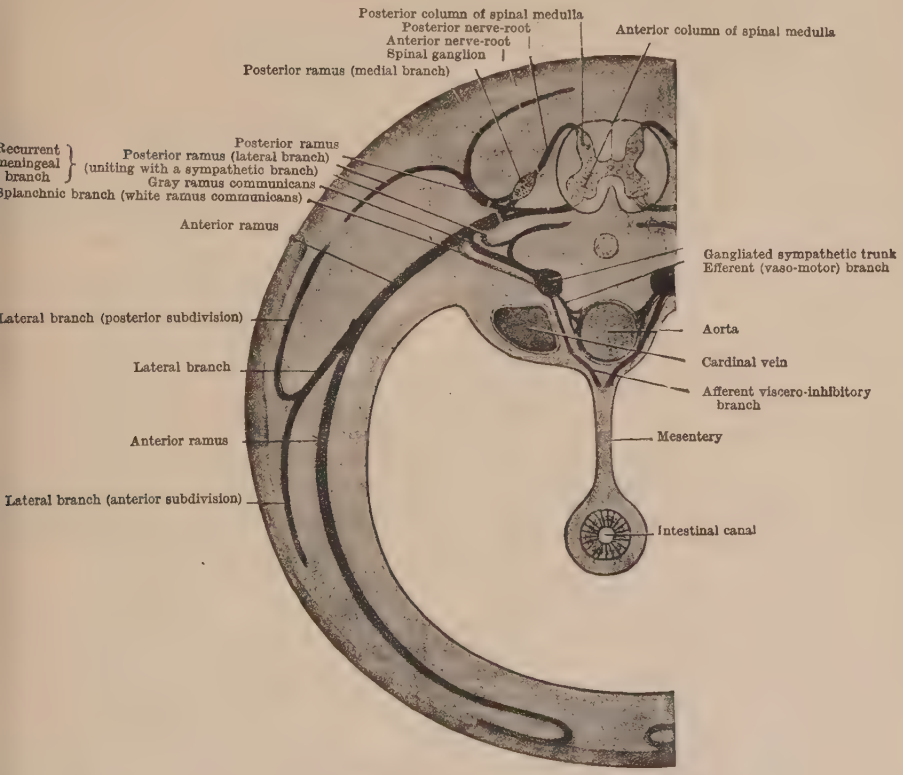


FIG. 2.—Scheme of the Distribution of a Typical Spinal Nerve.

ated in turn with similar dendritic processes of nerve fibres, which, descending in the direct and crossed pyramidal tracts of the spinal cord, convey motor impulses from the brain.

An afferent axon, traced centrally through the nerve, enters the dorsal ganglionic root, and joins a cell in the dorsal ganglion.

These ganglionic cells are unipolar. Each possesses a short protoplasmic prolongation which subdivides into peripheral and central axons. The peripheral axon is the afferent nerve fibre. The central axon forms one of the root fibres of the dorsal ganglion, and enters the spinal cord. Within the cord (posterior column) this axon subdivides into ascending and descending filaments, from which short dentritic processes (collaterals) arise. These again are connected with the dendritic processes of nerve cells in the dorsal horn of the spinal cord, from which nerve filaments pass upwards to the brain in the posterior and lateral columns of the cord.

A typical nerve, such as the ulnar, consists of a number of funiculi—bundles of nerve fibres—imbedded in connective tissue which forms a sheath for the nerve (epineurium), septa, and a matrix, in which the funiculi run (perineurium) continuous with fine connective, interstitial tissue lying between and among the nerve filaments composing each funiculus (endoneurium). The epineurium carries the larger vessels and lymphatics supplying the nerves along with nerves, **nervi nervorum,** which supply the nerve sheaths.

The perineurium contains a not very large supply of capillaries for the supply of the funiculi.

These connective tissue envelopes consist for the most part of white fibrous tissue, with an admixture of a reticulum of yellow elastic fibres.

A funiculus consists of a number of individual nerve fibres embeddedin a delicate connective tissue matrix(endoneurium).

The nerve fibres are for the most part of the kind known as **medullated.** Intermingled with these are a small number of **non-medullated** fibres.

A medullated nerve fibre in a peripheral nerve is composed of three elements: (1) Axon or axis-cylinder, the peripheral protoplasmic prolongation of the nerve cell; (2) Medullary sheath, or myelin sheath; and (3) Primitive sheath or neurolemma (Fig. 4).

Nerve fibres within the brain and spinal cord lack the neurolemma. Fibres (non-medullated) arising from sympathetic ganglia possess for the most part no myelin sheath.

The axis-cylinder, or axon, consists of a fibrillated proto-

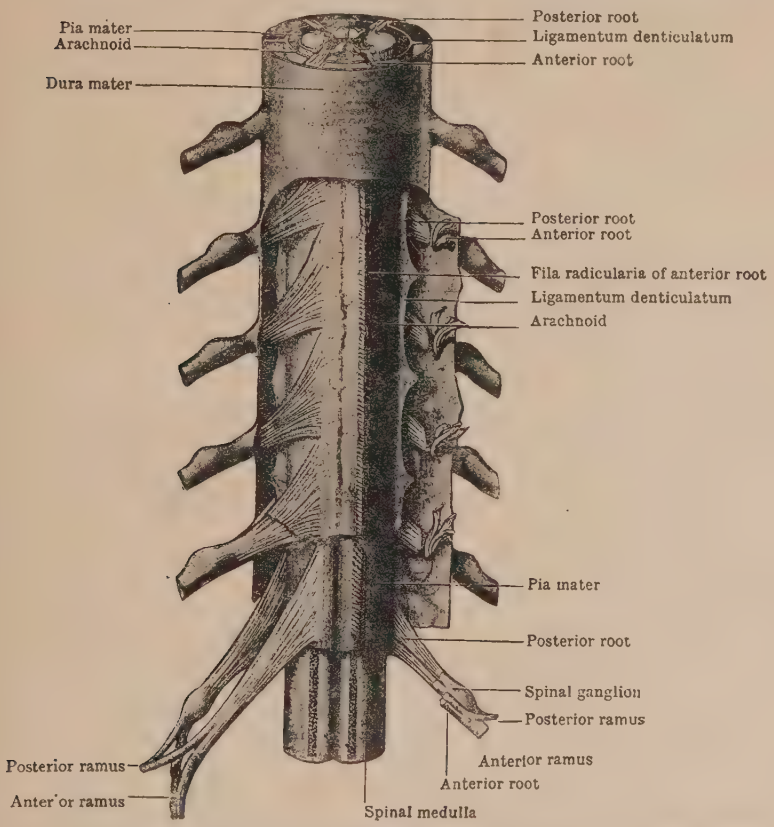


FIG. 3.—The Membranes of the Spinal Cord and the Roots of the Spinal Nerves.

plasmic filament, continuous without subdivision from origin to termination.

The medullary sheath forms a series of cylinders of myelin, surrounding the axon. The myelin is said to be a derivative of the protoplasm of the axon. It does not form one continuous sheath, but is broken at intervals

(**nodes of Ranvier**) where the axis-cylinder passes for a short distance without a covering of myelin. These nodes correspond to a nucleated stretch of the primitive sheath or neurolemma.

The neurolemma is a delicate membranous envelope which surrounds the nerve fibre continuously outside the medullary sheath. Midway between two nodes of Ranvier a nucleus is found on its inner surface, often associated with a small amount of protoplasm (Fig. 4).

The axon is, as already stated, a cell process.

The medullary sheath (myelin) is generally looked upon as a derivative of the axon.

The neurolemma may be of epiblastic or mesoblastic

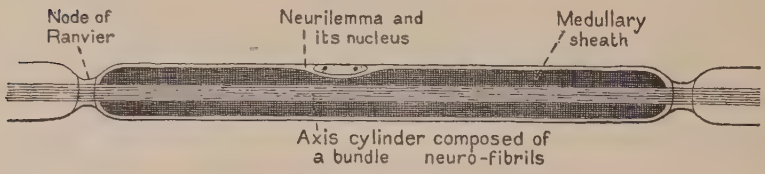


FIG. 4.—Structure of a Nerve Fibre showing Sheaths—Longitudinal view.

origin. It may be that cells migrate from the dorsal ganglion or from the medullary tube with the axon, or it may be that mesoblastic cells apply themselves to the axon on its liberation from the ganglion or the medullary tube, and give rise to this envelope.

This is the most probable, (1) from evidence afforded by the observation of growing nerves, and (2) from the fact that nerve fibres within the brain and spinal cord lack this sheath. Moreover, the sympathetic fibres, closely associated with the mesoblast in development, possess this sheath only.

Nutrition of a Nerve Fibre.—Our knowledge on this point is remarkably defective. It is asserted that all the trophic influence affecting a nerve is derived from the nerve cell. Presumably, therefore, the vessels supplying a nerve trunk are engaged solely in the nutrition of its connective tissue envelopes. Yet a nerve trunk is remarkably vascu-

lar. Each nerve of any moderate size has a companion artery. There is, for example, a *comes nervi vagi*. When the bulbs at the central and peripheral ends of a divided nerve are cut away, a considerable artery spouts at each end. The presence of this divided artery in the centre of the end of the distal portion of the nerve indicates that by anastomosis from collateral vessels and capillaries the central artery is kept supplied with blood. This vascular supply must have some trophic influence on the essential parts of the nerve trunk.

Degeneration of a Peripheral Nerve.—Here again further precise knowledge is needed. It is said that the central portion of a divided nerve remains actively functional, but that immediately after section the distal portion undergoes progressive degeneration, which is asserted to be irreparable. The myelin sheath shows degenerative changes first of all; becoming rapidly converted into oil globules, and later into granular protoplasm. The axon disintegrates and disappears, so that only connective tissue elements remain.

This process is said to affect the whole length of the distal portion of the nerve at one and the same time.

In view of the investigations made, and the "experiments" by means of nerve suture in recent military cases, this view needs reconsideration. Living fibres are found in the distal as well as the proximal portion of a divided nerve. On each is to be found a bulb at the point of division, and the bulb on each contains new growing axons derived from the cut ends of the nerve fibres.

Regeneration of Nerves.—It is asserted that when a nerve is cut the whole of the distal portion of the nerve degenerates entirely, and that after suture all regeneration occurs by the growth of axons from the proximal portion—either in or alongside the degenerated fibres.

Clinical experiments by no means support this view. If a nerve is accidentally cut in a surgical operation, and sutured at the time, restoration of function has been known

to occur within a month, although of course it is impossible to unite the cut ends of the nerve so that each axis-cylinder joins its own cut end. Suture of a nerve on the battle-field a few hours after the wound has shown rapid restoration of function, and numerous cases of nerve suture in hospital, weeks and months after the lesion has occurred, have resulted in some cases in extraordinarily rapid recovery of function, complete or partial. These results appear to occur in relation to any nerve lesion—brachial plexus, musculo-spiral, median, ulnar, great sciatic, and popliteal nerves.

Furthermore, long after division of the nerve trunk, live fibres are found in the distal portion of the nerve. Further investigation is needed on the subject.

Extensibility of a Nerve.—A nerve trunk is not elastic. A dead nerve stretched to its limits can support a weight of 10–12 lb. without showing any sign of lengthening. At the same time the living nerve is to a certain extent extensible. It becomes wavy in its course when relaxed, and straight in an extended position, so as to be adaptable to the movements of the joint over which it may travel. For example, the median and ulnar nerves are stretched to their limits when the extended arm is raised above the head. The ulnar nerve is stretched in flexion and the median nerve in extension of the forearm. But there is no power of stretching a nerve beyond its limit of extensibility, except by adapting the position of the limb to the normal course of the nerve.

Development and Morphology of the Spinal Nerves

The development of the spinal nerves is one of the earliest and most important events in embryonic growth. It has a fundamental effect in determining vertebral segmentation, on which depends the main architecture of the skeleton.

Each spinal nerve arises by two roots, dorsal and ventral, each being formed in a different way.

The element of the dorsal root is the first to appear, often before the closure of the medullary tube, in the form of a **ganglionic crest,** an unsegmented plate of cells growing outwards from the dorsal aspect of the medullary tube or from the dorsal angle of the medullary groove (Fig. 5).

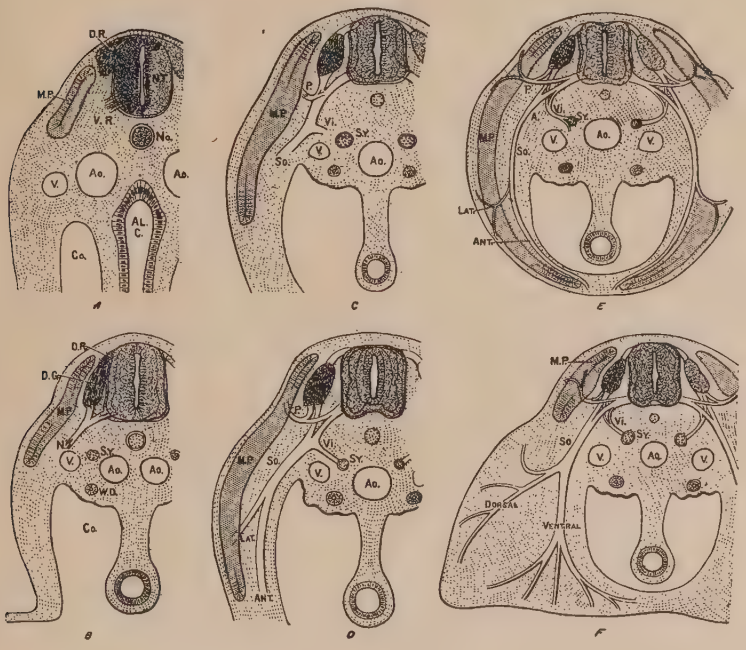


FIG. 5.—Development of a Spinal Nerve.

This cellular band gives rise to the dorsal ganglia in the following way: Its cells are at first ovoid or fusiform. Each cell gives rise to a pair of processes, one central, the other peripheral. The two processes soon unite at their junction with the cell (owing to changes in the growth of the cell body), so that the cell becomes "unipolar."

The central process passes inwards to join the medullary

tube; the peripheral process becomes the dorsal afferent (sensory) fibre of a spinal nerve.

While this interstitial process is going on the ganglionic crest becomes notched at its peripheral border, so as to produce segmental dorsal ganglia and nerve roots.

The ventral nerve roots arise as the axons of multipolar nerve cells in the ventral (basal) portion of the medullary tube. They appear between the twenty-fourth and twenty-eighth day. Streaming out in a linear series from the neural tube, they are gathered together into segmental bundles, which join the fibres from the dorsal ganglia to produce the "mixed spinal nerve."

The nerves determine spinal segmentation. A vertebral segment consists essentially of a nerve and the corresponding muscle element. The vertebræ and ribs and the intercostal vessels are essentially intersegmental.

Further development of a Nerve.—Thus formed, a typical segmental spinal nerve grows outwards, and very soon subdivides into two branches—the posterior and anterior primary divisions.

The **posterior primary division** passes backwards and divides again into two branches—external and internal—of which one supplies muscles, while the other is cutaneous (Fig. 6).

The muscular branches of the posterior primary divisions innervate the longitudinal muscles of the back; the cutaneous branches supply strips or segments of skin corresponding roughly to the posterior one-third of the circumference of the trunk. Owing to the development of the skull and limbs, these cutaneous nerves are concerned also in the innervation of (1) the back of the cranium, (2) the region of the shoulder, and (3) the buttock (Fig. 7).

The **anterior primary division** of the nerve, after separation from the posterior primary division, passes downwards and outwards through the body wall, and in the case of the thoracic, lumbar, and certain (second and third) sacral nerves, divides into two unequal branches—a large somatic

branch and a small visceral or splanchnic branch. The latter forms the **white ramus communicans**, and passes inwards into the splanchnic area to be associated with the sympathetic gangliated cord in the supply of nerve fibres to viscera and vessels.

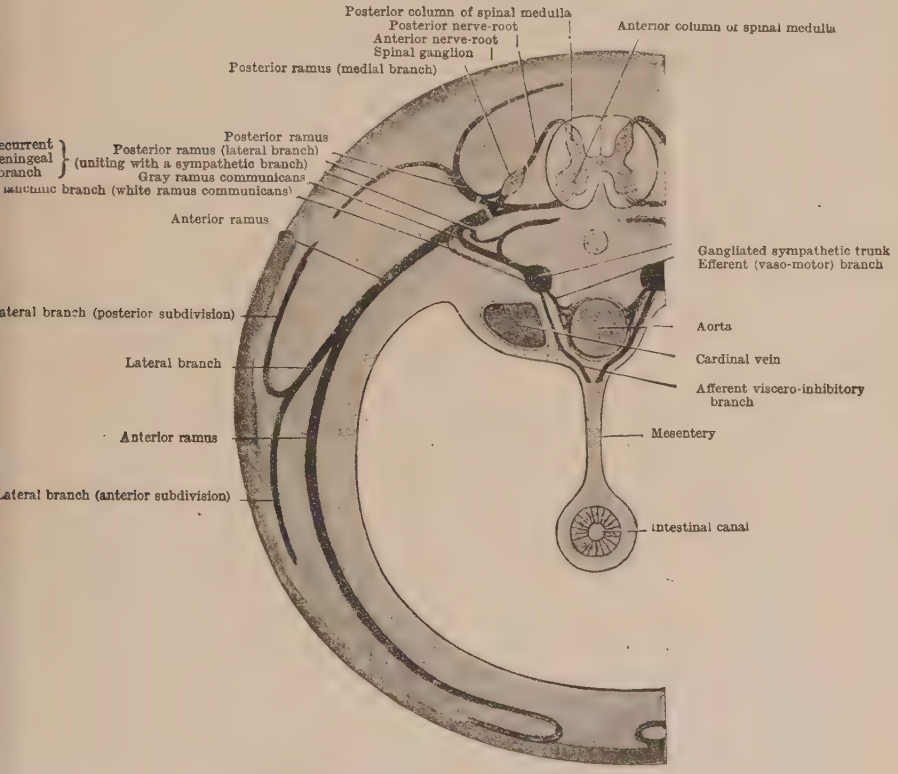


Fig. 6.—Scheme of the Distribution of a Typical Spinal Nerve.

The main (somatic) part of the anterior primary division enters the body wall, and grows downwards to the ventral aspect of the trunk. It soon subdivides into two parts, each containing motor and sensory fibres: the lateral branch, which supplies muscles of the trunk and the skin of the lateral third of the trunk; and the anterior branch,

which, after supplying muscles, terminates as a cutaneous nerve on the ventral aspect of the trunk.

The several cutaneous branches of any one nerve supply

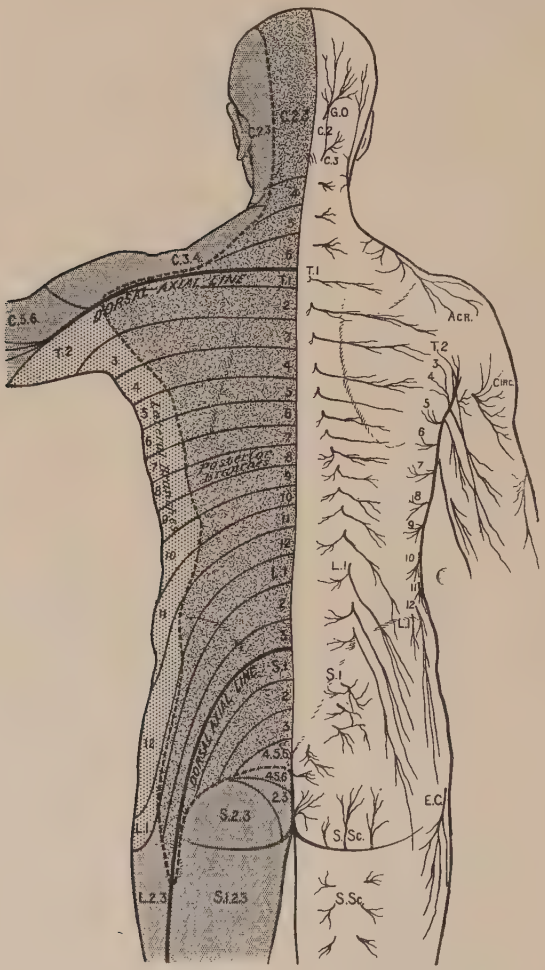


FIG. 7.—Innervation of the Skin of the Back.

areas of skin which form continuous strips between the mid-dorsal and mid-ventral lines of the trunk.

The motor branches supply the axial muscles—the

longitudinal muscles of the back and neck, the segmental intercostal muscles, and the muscles of the anterior abdominal wall.

Nerve Plexuses in connection with the Posterior Primary Divisions

There are two rudimentary plexuses among the posterior primary divisions of certain spinal nerves which serve to illustrate the significance of the more complex plexuses that occur among the anterior primary divisions.

Posterior Cervical Plexus.—Loops of communication take place between the posterior primary divisions of the first four cervical nerves, from which branches pass to supply the muscles of the back of the neck. Just as these muscles are derived from the fusion of cervical myotomes, so the corresponding nerves unite so that parts of each muscle receive fibres from more than one spinal nerve.

Posterior Sacral Plexus.—The cutaneous branches of the first three sacral nerves (joined by fibres from the fifth lumbar and fourth sacral nerves) form a similar series of loops from which branches pass to supply the skin over the back of the sacrum.

Anterior Primary Divisions.—It has been seen that the somatic part of the anterior primary division of a spinal nerve divides into two parts, a lateral and an anterior branch. These are found in a typical form only in the thoracic region (second—twelfth thoracic nerves).

In other regions plexuses are formed which at first sight present radical alterations from this type. But in all the plexuses the homology with the original embryonic type can be made out.

Limb Plexuses

The limb plexuses are of great morphological as well as practical interest.

There are two great limb plexuses—brachial and lumbosacral—for the upper limb and lower limb. Closely

associated with the lumbo-sacral plexus is the pudendal plexus, essentially appertaining to the perineum and parts beyond the lower limb.

The limb plexuses have certain features in common. Each is formed by the anterior primary divisions of certain spinal nerves, which supply branches (except at the margins of the limbs) only to the limbs, and not to the trunk at all. Except the last nerve in the plexus each component nerve divides on entering the plexus into dorsal (posterior) and ventral (anterior) branches, which after various subdivisions unite with neighbouring dorsal and ventral trunks—dorsal with dorsal, ventral with ventral—to form nerves of distribution. The last nerve in each limb plexus—the first thoracic and the third sacral—do not as a rule contribute a dorsal or posterior trunk.

The nerves of distribution formed by the union of dorsal trunks supply the parts of the limb primitively dorsal, while the nerves formed by the union of ventral trunks supply the parts primitively ventral in position.

The dorsal and ventral branches are homologous with the lateral and anterior branches of the thoracic nerves.

Nature of Limbs

To understand properly the limb plexuses and the distribution of the nerves to the limbs, a brief reference must be made to the problem of the development and morphology of the limbs.

Herbert Spencer suggested that vertebrate segmentation arose from the needs of a worm-like animal to obtain food or escape its enemies. A wriggling movement being necessary would cause transverse cleavage and segmentation.

Following on this is the formation of the segmented animal with limbs—the annulose invertebrate with parapodia—segmental limbs, containing segmental muscles, vessels, and nerves.

In **Amphioxus**, the lowest vertebrate, a free swimming animal, limb elements are represented by a fold or flap

alongside the trunk, composed of elements derived from vertebral segments which are fused together. The muscular elements are derived from myotomes, and segmental nerves enter and supply the segments of the fold.

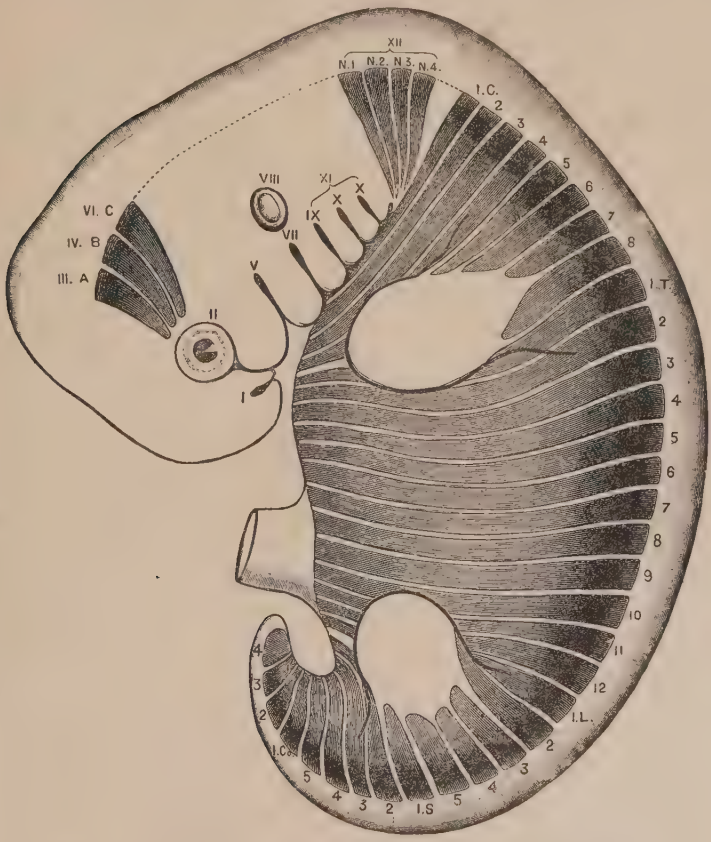


Fig. 8.—The Myotomes and their Morphological Relations.

In **Elasmobranch fishes** many vertebral segments contribute to the formation of the pectoral and pelvic limbs.

The myotomes contribute segmental muscular elements, growing with the limb, and forming dorsal and ventral strata of muscles. Segmental nerves also extend into the limb, to be distributed to the muscles and skin.

In **reptiles, birds**, and **mammals,** certain modifications occur in relation to the development of the limbs (Fig. 8).

Development of the Limbs in Mammals

In the development of the trunk generally, a process of transverse vertebral segmentation proceeds in relation to the main longitudinal structures occupying the median plane—the neural tube, notochord, aorta, and alimentary canal.

The spinal nerves and the myotomes represent the essentially segmental structures, while the vertebræ themselves, with their neural arches, the ribs, and the intercostal vessels, are intersegmental in character. The myotomes growing downwards in the body wall become the intercostal muscles and the muscles of the abdominal wall, while the nerves form the intercostal nerves, their anterior primary divisions dividing into lateral and anterior branches.

The Limb-buds.—The pectoral and pelvic limbs develop at the extremities of a slight evanescent ridge, which extends along the side of the trunk. The pectoral limb-bud grows from the side of the trunk, just caudal to the last branchial arch—at the junction of neck and thorax. The pelvic limb-bud arises just anterior to the cloaca (perineum). Each is flattened, and presents a dorsal and a ventral surface, a cephalic and a caudal border.

Each limb-bud consists of a mass of blastema (mesoblast) covered by a layer of epiblast. Each corresponds to a number of vertebral segments, the number being not necessarily the same in the fore and hind limbs in the same animal, or in the corresponding limb in different groups of mammals. In man, the upper limb-bud is associated with more than five vertebral segments, while the lower limb-bud abstracts elements of more than seven.

The blastema forming the bud grows out from the lower (ventral) two-thirds of the trunk in the region in which it occurs (Fig. 9).

The most important morphological elements in the

composition of the limb are the spinal nerves. The myotomes in the regions of limb development do not enter into its composition, but stop short at the root of the limb. The skeleton, muscles, and vessels of the limb are formed in situ, out of the formative blastema of the bud (Fig. 8).

The anterior primary divisions of the nerves of the segments, in relation to which the limb is developed, grow out into the bud. Except at the borders, where portions of the nerves may be engaged in supplying both limb and

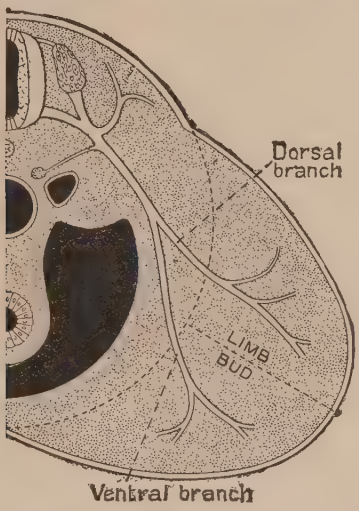


Fig. 9.—Growth of Limb-Bud (Transverse Section).

trunk (*e.g.* intercosto-humeral and small sciatic), the whole of the nerve enters the limb-bud. Each divides into a dorsal and a ventral trunk, for the supply respectively of the dorsal and ventral surfaces of the limb-bud (Fig. 9). These subordinate trunks subdivide, and their branches reunite with those of neighbouring subdivisions—dorsal with dorsal, ventral with ventral branches—to form the limb plexuses, and the nerves of distribution to the limb. In the process of growth these dorsal and ventral nerve trunks appear at first as flattened plates on the dorsal and ventral aspects of the limb vessels (Fig. 9).

The other elements of the limb are formed in situ.

Skeleton.—The skeletal elements of each limb are laid down in the core of the bud. The component cells become closely conglomerated together and converted into hyaline cartilage, which by the formation of the joints is divided into several parts: shoulder or pelvic girdle, humerus or femur, radius and ulna or tibia and fibula, and the osseus elements of the hand or foot.

Muscles.—Beneath the dorsal and ventral surfaces of the limb-buds the cells of the blastema become fusiform, their long axes being directed at right angles to the trunk. The myotomes, or muscle-plates, stop short at the root of the limb, and take no share in the formation of the limb muscles. Instead, these fusiform cells of the blastema arrange themselves in double layers, superficial and deep, on the dorsal and ventral aspects of the bud, and give rise to the muscles of the limb.

Arteries.—Early in its development the limb-bud is permeated by a meshwork of capillaries (*angioblast*), from which the peripheral vessels are formed. In the case of the upper limb a junction is effected with the dorsal aorta in the neighbourhood of the fourth branchial artery by means of the subclavian artery. In the lower limb there are two arteries engaged, the sciatic and external iliac. In man these arteries join the umbilical arteries, the sciatic becomes subordinate, the external iliac becoming the main (femoral) artery. In birds the sciatic artery is the main artery for the lower limb.

Further changes in the Limb-bud.—At first the bud is a flattened fold with dorsal and ventral surfaces, and with cephalic and caudal borders.

Formation of the Digits.—The first change that occurs in the simple bud is by the formation of four notches along its peripheral margin. Thereby the rudiments are formed of the five digits. (It is to be remembered that the digits are secondary, and have no relation to the primary vertebral segments.) The thumb or great toe is at the end of the

cephalic border; the little finger or little toe, at the end of the caudal border (Fig. 10).

Elongation and Angulation.—As further growth occurs, the bud is elongated and at the same time angulated, along with the formation of the several parts of the limb, shoulder or pelvis, arm or thigh, forearm or leg, hand or foot. Each limb is bent, so that the elbow or knee and the digits of the hand or foot are at first directed outwards.

Torsion.—While the processes of elongation and angulation are going on, the whole limb is being twisted on itself. But the twisting is in opposite directions in the upper and lower limbs. It is in a caudal direction in the upper limb, and in a head-ward direction in the lower limb, so that the elbow is rotated backwards and the knee forwards. The result is that the original dorsal surfaces of the primitive limb-bud look towards one another.

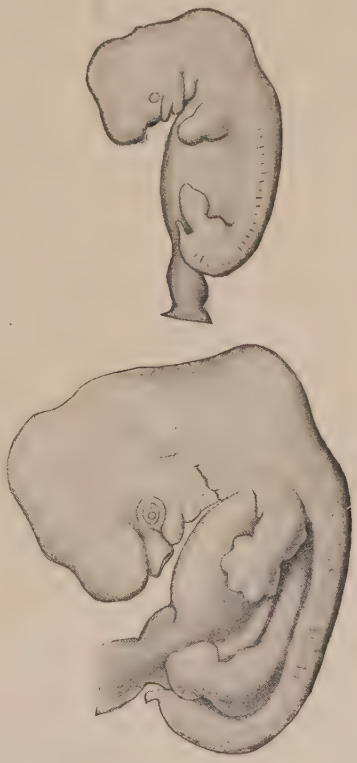


FIG. 10.—Elongation and Angulation of Limb.

Pronation.—The hind limb-bud has now gained its permanent quadrupedal position. But a secondary change takes place in the fore or upper limb, by a rotation or movement of pronation of the forearm and hand, by which the bones of the forearm become pronated, and the hand (or fore foot) is brought round, so that the digits project forward. In a quadruped this posture is permanently

adopted. In man the limb retains its mobility, and the power of pronation and supination.

The final result is that in both limbs there are surfaces which correspond to the dorsal and ventral surfaces of the primitive limb-buds, respectively supplied by nerves which are derived from dorsal and ventral branches of the nerves which form the limb plexuses and supply the buds.

The *dorsal surface of the upper limb-bud* becomes the region of the shoulder, the back of the arm, forearm, and hand—supplied by nerves which are dorsal or posterior in origin—circumflex and musculo-spiral.

The *ventral surface* becomes the front of the chest, front of the arm, forearm, and hand—supplied by nerves which are ventral or anterior in origin—anterior thoracic, musculo-cutaneous, median, and ulnar.

The *dorsal surface of the lower limb-bud* becomes the front of the thigh and buttock, the front of the leg and the dorsum of the foot—supplied by nerves which are dorsal or posterior in origin, gluteal, anterior crural, and peroneal or external popliteal.

The *ventral surface* becomes the inner side and back of the thigh, the back of the leg, and the sole of the foot—supplied by nerves which are ventral or anterior in origin —obturator, nerve to the ham-strings, and tibial or internal popliteal.

CHAPTER II

DISTRIBUTION OF THE SPINAL NERVES

THERE are thirty-one pairs of spinal nerves: eight cervical (the first or suboccipital arising between the occipital bone and atlas), twelve thoracic, five lumbar, five sacral, and one coccygeal.

Origin.—As a rule each nerve arises by two roots, one dorsal, ganglionic and afferent; the other ventral, non-ganglionic and efferent. (The suboccipital nerve may lack a dorsal root, or its ganglion may be rudimentary.)

The root filaments pass out from their junction with the spinal cord, piercing the membranes enclosing the cord, horizontally in the neck, but more and more obliquely in the lower roots. Owing to the termination of the spinal cord opposite to the lower border of the first lumbar vertebra, the roots of the lumbar, sacral, and coccygeal nerves pursue a lengthy course within the spinal canal around the filum terminale, and constitute the **cauda equina.**

The dorsal ganglion occupies the intervertebral foramen (except in the case of the lower nerves which form the cauda equina. The ganglia on the dorsal roots of these nerves are within the foramina, in the spinal canal). The dorsal and ventral roots unite as they pierce the dura mater to form the "mixed spinal nerve," which emerges from the intervertebral foramen, and at once divides into two unequal parts—a smaller **posterior primary division** and a larger **anterior primary division** (Fig. 3). The former in general supplies the muscles and skin of the back, while the latter is distributed to the muscles and skin of the lateral and ventral aspects of the trunk, and of the limbs.

Typical segmental nerves are found only in a limited region of the trunk, as the formation of the various plexuses to a large extent masks or obliterates the segmental

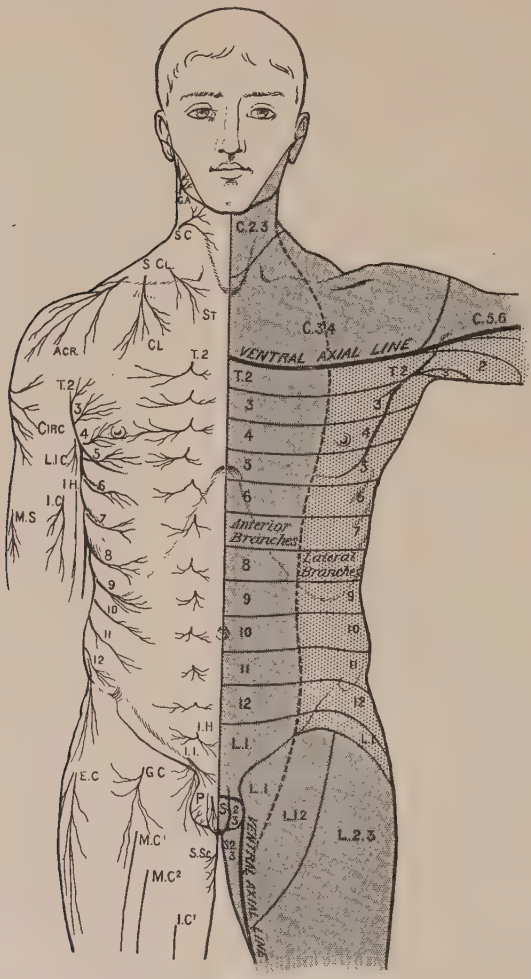


FIG. 11.—Distribution of Nerves to the Skin of the Trunk.

character of the nerves. The thoracic nerves from the second to the twelfth are alone distributed in a segmental manner (Fig. 6).

Posterior Primary Divisions

Each posterior primary division proceeds backwards, and subdivides as a rule into internal (medial) and external (lateral) branches. These are distributed in a different way in the upper and lower parts of the back. In the upper region, down to the sixth thoracic nerve, the internal branch is cutaneous, the external branch muscular. In the lower region the external branch is cutaneous, the internal branch muscular in its distribution.

Distribution to Skin.—The posterior primary divisions of the nerves innervate in a segmental manner an area of skin shown in the figure (Fig. 7).

In relation to the back of the head, the shoulder, and buttock, the nerves are prolonged beyond their proper regions so as to innervate the skin of these outside areas. Thus the back of the scalp is supplied by the posterior primary divisions of the second and third cervical nerves (**Great Occipital** and **Least Occipital**), the scapular region is supplied by the upper thoracic nerves, and the buttock receives branches from the first three lumbar nerves.

The posterior primary divisions of certain spinal nerves do not provide cutaneous branches. The first cervical (suboccipital) nerve, the seventh and eighth cervical nerves, and the fourth and fifth lumbar nerves supply no cutaneous branches.

Distribution to Muscles.—The muscles supplied by the posterior primary divisions are exclusively the longitudinal muscles of the back. No limb muscle is innervated by these nerves.

Plexuses

Illustrations of the simplest form of nerve plexus are to be found in the distribution of the posterior primary divisions of the spinal nerves.

(*a*) **Posterior Cervical Plexus.**—Loops of communication occur between the posterior primary divisions of the first

four cervical nerves, from which branches are supplied to the deep longitudinal muscles of the neck, thus ensuring that each muscle shall receive its innervation from more than one spinal nerve.

(*b*) **Posterior Sacral Plexus.**—The posterior primary divisions of the first three sacral nerves form loops, joined by twigs from the fifth lumbar and fourth sacral nerves, from which secondary branches supply the skin over the back of the sacrum.

(*c*) **Posterior Sacro-coccygeal Nerve.**—This is formed by the union of part of the posterior primary division of the fourth sacral nerve with the fifth sacral and the coccygeal nerves, to form a nerve which supplies the skin in the neighbourhood of the coccyx. This nerve is the rudiment of the **superior caudal nerve** of tailed animals, which, formed by numerous spinal nerves, is distributed to the muscles and skin of the tail.

Anterior Primary Divisions

A. Typical Thoracic Segmental Nerves

The anterior primary division of a typical spinal nerve is distributed in the following way (Fig. 6):

Recurrent Branch.—Soon after its separation from the posterior primary division a small recurrent branch is supplied from it to the roots of the spinal nerves and the meninges of the spinal cord.

It then divides into two very unequal parts—somatic and splanchnic. The **somatic** portion comprises the greater part of the nerve, and is distributed to the body wall, The **splanchnic** branch is a fine branch which is directed inwards, to supply structures in the splanchnic area. through the medium of the sympathetic system. The splanchnic branches constitute the **White Rami Communicantes**, and are only found in relation to certain spinal nerves (second thoracic to third or fourth sacral) (Fig. 12).

All the anterior primary divisions of the spinal nerves receive branches also from the gangliated cord of the sympathetic, in the form of **Grey Rami Communicantes.** The distribution of the grey and white rami communicantes will be dealt with in connection with the sympathetic system.

The **somatic** part of the anterior primary division comprises the main portion of the nerve. Carried out into the body wall it divides into two parts, **lateral** and **anterior,** each responsible for the innervation of skin and muscles, on the lateral and ventral aspects of the trunk respectively.

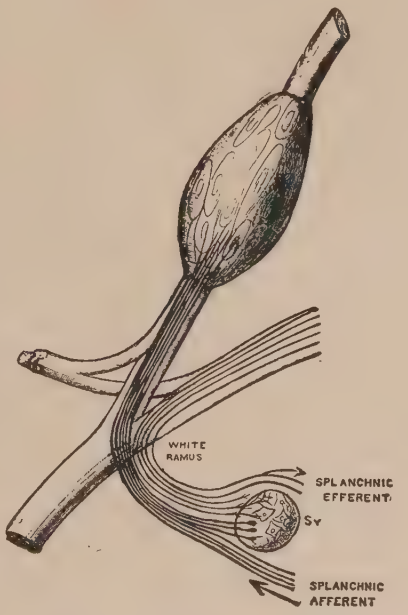


Fig. 12.—Connection of Spinal Nerves and Sympathetic System.

The arrangement is such that in the innervation of the skin each typical segmental nerve supplies one continuous belt of skin from the middle line behind to the middle line in front, through the medium of the cutaneous branches of the posterior primary divisions, and the lateral and anterior branches of the anterior primary divisions (Figs. 7 and 11).

There are differences in the course and distribution of the upper and lower nerves in this series.

(*a*) **Upper Thoracic Nerves.**—The nerves from the second to the sixth thoracic are purely intercostal. Each lies at first in the subcostal groove, between the external and internal intercostal muscles. After giving off its lateral branch, which pierces the intercostal muscles and sub-

divides into anterior and posterior trunks for the supply of the skin of the side of the chest, the anterior branch pierces obliquely the internal intercostal muscle, and comes to lie between it and the parietal pleura. Proceeding onwards the nerve passes in front of the internal mammary artery and triangularis sterni muscle, passes through the internal intercostal muscle and the anterior intercostal aponeurosis, and finally becomes cutaneous at the side of the sternum.

The first thoracic nerve is mainly engaged in the formation of the brachial plexus. It gives off a small intercostal branch to supply the muscles of the first intercostal space. It gives off as a rule no lateral or cutaneous branches.

(*b*) **Lower Thoracic Nerves.**—The course of the lower thoracic nerves is similar in the proximal part of their course. Reaching the costal arch, however, each passes forwards beneath the costal cartilages and between the obliquus internus and transversalis muscles, and piercing the posterior layer of the aponeurosis of the obliquus internus, enters the sheath of the rectus abdominis muscle. After piercing this muscle and the anterior lamella of its sheath, it becomes cutaneous in the anterior abdominal wall (Fig. 11).

Distribution to Muscles.—The upper thoracic nerves supply the intercostal muscles and triangularis sterni. The lower nerves supply the intercostal muscles and the muscles of the abdominal wall.

Distribution to Skin.—As in the case of the cutaneous distribution of the posterior primary divisions, there is found an extension of the areas of distribution of the anterior primary divisions of these nerves to other regions.

The anterior trunks are limited in the area of their distribution, which extends (Fig. 11) from the manubriosternal junction to a point midway between the umbilicus and the pubes. The second thoracic nerve innervates the area of the second intercostal space near the sternum, the seventh is distributed over the ensiform cartilage, the

tenth over the umbilicus, and the twelfth over an area midway between the umbilicus and the pubes.

The lateral branches are carried out to the limbs at each end of the series. While from the fourth to the tenth each nerve subdivides into anterior and posterior trunks for the supply of the skin of the lateral wall of the chest and abdomen, at the upper end, the second and third thoracic nerves are carried to the arm, and at the lower end the eleventh and twelfth nerves are carried to the buttock.

Intercosto-humeral Nerve. — This nerve, the lateral branch of the second thoracic nerve, is usually a large trunk, which, after piercing the chest wall, crosses the axilla, and is distributed to the skin of the arm as low down as a point between the internal condyle and the olecranon process. It does not divide into anterior and posterior trunks. It is joined by two other nerves in its course, —the lesser internal cutaneous from the brachial plexus (T 1), and the posterior trunk of the lateral branch of the third thoracic nerve—so that a considerable area of skin on the inner side of the arm is supplied by the first three thoracic nerves (Fig. 11).

Innervation of the Buttock.—Anterior to the area innervated by the posterior primary divisions of the first three lumbar nerves, the lateral branches of the eleventh and twelfth thoracic nerves sweep over the iliac crest and supply a large area down to the level of the front of the great trochanter of the femur (Figs. 7, 11).

B. The Plexuses

Apart from these comparatively simple nerves the anterior primary divisions of the spinal nerves are engaged in the formation of four great plexuses—cervical, brachial, lumbo-sacral, and pudendal.

Significance of Plexuses.—A study of the plexuses shows that there are two great ideas involved in their formation—the one morphological, the other physiological. The

morphological idea is associated with the modifications that have occurred in the development of the regions which they serve—the neck, limbs, and perineum. The physiological idea is to provide for the innervation of every muscle and of every spot of skin by more than one spinal nerve.

Starting from the simple segmental nerve with its lateral and anterior subdivisions, supplying the lateral and ventral parts of the trunk, we find the same subdivision of nerves in the plexuses, but modified in different ways in each case.

Cervical Plexus

Formed by the first four cervical nerves, this plexus gives rise to numerous branches, of which nearly all can be

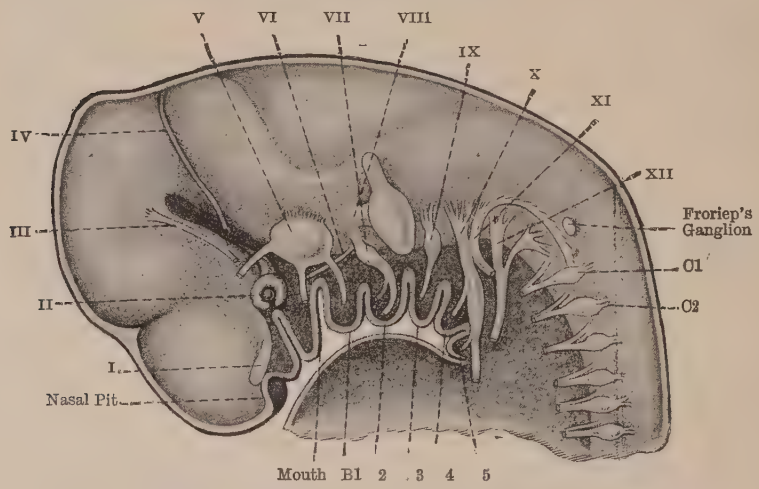


Fig. 13.—Embyro Head to show Gill Arches and Cranial Nerves

homologised with the lateral and anterior branches of a typical spinal nerve. It is to be remembered that morphologically the region innervated by these nerves is very circumscribed, being limited above by the head, below by the root of the upper limb, and in front by the gill arches and clefts (supplied by cranial nerves) (Fig. 13).

The nerves in question form a series of loops under cover of the sterno-mastoid muscle at the side of the neck. Either from these loops or from the individual nerves a series of branches arise which may be classified as follows:

Superficial:

(*a*) Ascending:

Small occipital	(C 2, 3)
Great Auricular	
Superficial cervical	

(*b*) Descending: (supraclavicular)

Sternal	(C 3, 4)
Clavicular	
Acromial	

Deep:

(*a*) External:

(1) Muscular:

Sterno-mastoid	(C 2)
Trapezius	(C 3, 4)
Levator scapulæ	(C 3, 4)

(2) Communicating:

To Spinal accessory	(C 2, 3, 4)

(*b*) Internal:

(1) Muscular:

Prævertebral muscles	(C 1, 2)
Phrenic	(C 3, 4)

(2) Communicating:

Vagus	(C 1, 2)
Sympathetic	
Hypoglossal	
Communicantes hypoglossi	(C 2, 3)

The superficial group of nerves is wholly cutaneous, while the deep branches are mainly muscular in their distribution.

The **Superficial Branches** supply an area of skin, including the side of the neck, the scalp, lower part of pinna and

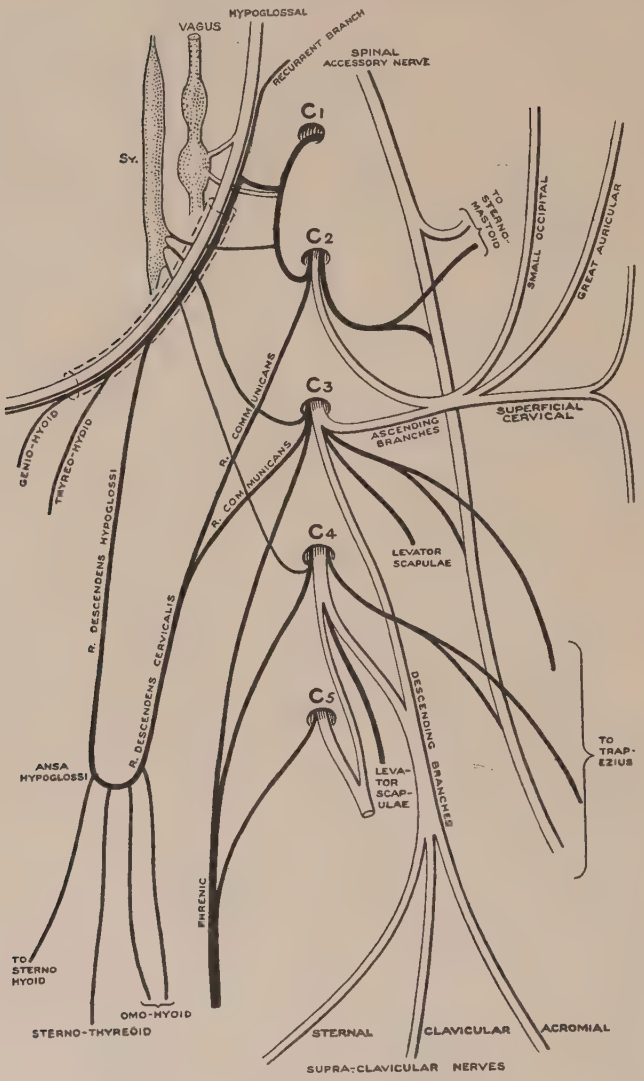


FIG. 14.—The Cervical Plexus.

face, and the front of the chest down to the level of the nipple, as well as the upper half of the deltoid region (Figs. 7, 11).

The deep branches innervate the following muscles :

Sterno-mastoid	(C 2)
Trapezius	(C 3, 4)
Levator scapulæ	(C 3, 4)
Prævertebral muscles	(C 1, 2)
Diaphragm (Phrenic)	(C 3, 4)
Sternohyoid, Sternothyroid, Omohyoid (Ansa hypoglossi)	(C 1, 2, 3)

The nerves to the sterno-mastoid and trapezius communicate with the spinal accessory nerve. Those to the trapezius cross the posterior triangle of the neck. The branches to the levator scapulæ come off directly from the anterior primary divisions of the third and fourth cervical nerves, and enter the superficial surface of the muscle.

The first and second cervical nerves form a loop over the atlas from which branches pass to supply the prævertebral muscles, and to form communications with the sympathetic, vagus, and hypoglossal.

Ansa Hypoglossi.—The trunk from the first and second cervical nerves communicating with the hypoglossal nerve is of considerable size. It is incorporated with the hypoglossal, and becomes responsible for the following nerves (in order) : recurrent branch descendens hypoglossi, nerve to the thyrohyoid muscle, and nerve to the geniohyoid. These muscles are thus supplied by the first and second cervical nerves.

The **Descendens Hypoglossi nerve** passes down the neck in front of the external and common carotid arteries. It is joined by the **Descendens Cervicis**, a nerve which is formed by the **Communicantes Hypoglossi**—branches of the second and third cervical nerves—and which passes obliquely inwards over the internal jugular vein and unites with the descendens hypoglossi to form the **Ansa Hypoglossi**—a loop from which branches supply the infrahyoid muscles—sternohyoid, sternothyroid, and omohyoid (Fig. 14).

The **phrenic nerve** is formed by the third and fourth cervical nerves (joined by a branch from the fifth). It passes down through the neck, lying deeply on the scalenus anticus muscle. After traversing the thoracic cavity it pierces the diaphragm and supplies it on its under surface.

It is to be noted that the ventral axial muscles between the chin and the abdomen are supplied in numerical order by the first five cervical nerves (Fig. 14).

Geniohyoid . . .	(C 1, 2)
Thyrohyoid . . .	(C 1, 2)
Infrahyoid muscles . .	(C 1, 2, 3)
Diaphragm (phrenic) . .	(C 3, 4, 5)

Homologies of the Nerves of the Cervical Plexus

A comparison of the nerves of the cervical plexus with the simple segmental nerves of the thorax shows a difficulty in establishing some of the homologies.

Of the superficial nerves, the small occipital and acromial branches of the supraclavicular series are dorsal or posterior, and may be regarded as homologous with the lateral branches of the segmental nerves. The superficial cervical and sternal nerves are homologous with the anterior trunks. The great auricular and clavicular nerves are border-line nerves, partaking of the character of both lateral and anterior trunks.

Of the deep branches, the external series are homologous with lateral branches, the internal series with anterior branches of a typical segmental nerve.

The Limb Plexuses

A. Brachial Plexus

The nerves of distribution to the upper limb are formed by the Brachial Plexus. The plexus is situated in the posterior triangle of the neck and in the axilla. The nerves composing the plexus are the anterior primary

divisions of the last four cervical nerves, and the greater part of the first thoracic. The cervical nerves increase in size from above downwards. A small branch of communication passes from the fourth to the fifth cervical, and in the majority of cases there is a considerable intra-thoracic communication between the second and first thoracic nerves.

The first thoracic nerve, after supplying a small intercostal branch for the supply of the muscles of the first intercostal space, and receiving a trunk of communication from the second thoracic nerve, passes over the neck of the first rib, alongside the superior intercostal artery, and becomes closely associated with the eighth cervical nerve between the scalene muscles.

The constituent nerves emerge in the neck between the scalenus anticus and scalenus medius muscles, in close relation to the subclavian artery. The fifth, sixth, and seventh nerves are above, and the eighth cervical and first thoracic are directly behind the artery.

There are three stages in the formation of the plexus and the nerves of distribution :

(1) Subdivision of the anterior primary divisions into anterior and posterior trunks.

(2) Association of these trunks to form the so-called " cords " of the plexus—an outer and inner cord formed by the anterior trunks and situated on the outer and inner sides of the axillary artery ; and a posterior cord formed by the posterior trunks, situated behind the artery.

(3) The formation of collateral and terminal nerves of distribution to the limb from these so-called " cords."

Each of the nerves concerned (except, as a rule, the first thoracic) divides into an anterior (ventral) and a posterior (dorsal) trunk. When the eighth cervical and first thoracic nerves are separated, it is found that as a rule there is no posterior trunk associated with the latter nerve. Occasionally a minute posterior filament is present, which joins the posterior trunk of the eighth cervical nerve.

The anterior trunks of the fifth, sixth, and seventh nerves are enclosed together in a fibrous sheath, and constitute the so-called " outer " cord of the plexus. The anterior trunks of the eighth cervical and first thoracic nerves are similarly enclosed, and form the so-called " inner " cord, while the posterior trunks of all four cervical nerves constitute together the so-called " posterior " cord.

In reality each nerve trunk **retains its individuality** in these " cords," and subdivides and again reunites, by means of its subdivisions, with neighbouring trunks, to produce collateral and terminal nerves of distribution.

Removal of the fibrous sheaths makes it possible to trace each nerve of distribution to its nerves of origin. By painting the nerve trunks with a dilute solution of nitric acid, the connective tissue envelopes are dissolved, and the nerve fibres are hardened, making the separation of individual nerves more easy.

Nerves of Distribution

A. Terminal Branches

Dealing first with the terminal branches, which are six in number, there are five derived from the " outer " and " inner " cords—musculo-cutaneous, median, ulnar, internal cutaneous, and lesser internal cutaneous. The origin of these nerves is from the anterior trunks of certain spinal nerves ; and their distribution is, with one exception (dorsal branch of the ulnar to the hand), to the anterior aspect of the limb. One branch, the musculo-spiral, is derived from the " posterior " cord, and is distributed entirely to muscles and skin on the back of the limb (Fig. 15).

The musculo-cutaneous nerve arises through the " outer " cord from the fifth and sixth cervical nerves. The median arises by two heads: an outer head from the " outer " cord (sixth and seventh cervical nerves); an inner head from the " inner " cord (eighth cervical and first thoracic).

The ulnar nerve and the internal cutaneous nerve ("inner" cord) arise from the eighth cervical and first thoracic nerves. The lesser internal cutaneous nerve, traced up through the "inner" cord, arises only from the first thoracic nerve.

The musculo-spiral nerve arises through the "posterior" cord from the posterior trunks of the last four cervical nerves (Fig. 15).

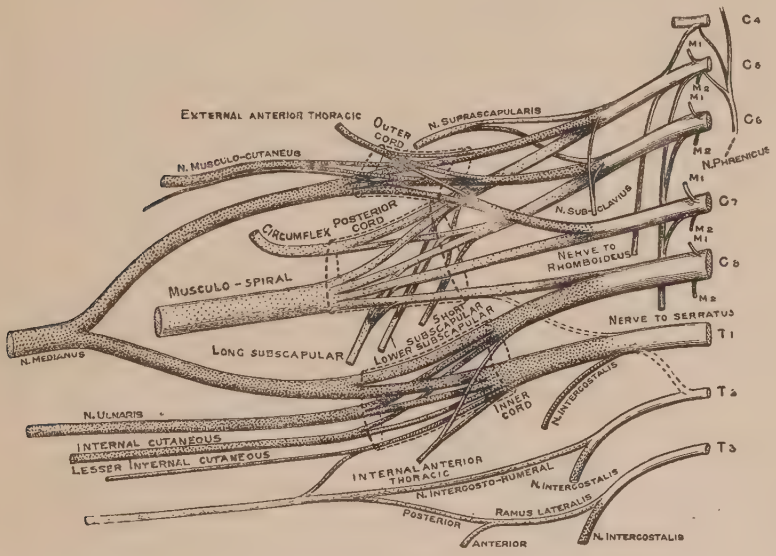


FIG. 15.—The Brachial Plexus.

B. Collateral Branches

In addition to the terminal branches distributed to the limb, two series of collateral branches are given off by the nerves forming the plexus—one set above and one below the clavicle.

1. Supraclavicular Branches.

These are six in number, and can for the most part be grouped in two series—anterior and posterior.

(*a*) **Anterior Branches.** (1) From the anterior primary

divisions of the lower four cervical nerves **muscular branches** are given off to the neighbouring axial muscles: longus colli, rectus capitis anticus major, and scaleni.

(2) **Communication with the Phrenic Nerve.**—The phrenic nerve formed from the third and fourth cervical nerves is reinforced by a branch from the fifth.

(3) **Nerve to the Subclavius.**—This small nerve is formed by the union of two roots from the front of the fifth and sixth cervical nerves. It passes down to the muscle in front of the subclavian vessels.

(*b*) **Posterior Branches.**—(4) **Suprascapular Nerve.**—This is the most cephalic of the branches of the brachial plexus. It is a considerable nerve, derived from the posterior trunks of the fifth and sixth cervical nerves. Passing behind the plexus it goes through the suprascapular foramen, and is distributed to the supraspinatus and infraspinatus muscles.

(5) **Posterior Scapular Nerve** (Nerve to the Rhomboids).—This nerve arises from the fifth cervical nerve before it emerges between the scalene muscles. It pierces the scalenus medius, and pierces or passes beneath the levator scapulæ on its way to supply the rhomboid muscles. It supplies a branch to the levator scapulæ muscle.

(6) **Posterior Thoracic Nerve** (Nerve to the serratus, external respiratory nerve of Bell).—This nerve is formed by three roots which arise from the back of the fifth, sixth, and seventh cervical nerves before their emergence between the scalene muscles. Piercing the middle scalene muscle below the posterior scapular nerve it descends behind the axillary artery into the axilla, where it supplies branches to each serration of the serratus magnus muscle.

2. Infraclavicular Branches

These are also six in number, and like the supraclavicular and terminal branches are derivatives of the anterior and posterior component trunks of the plexus.

The anterior trunks contribute two nerves, the posterior trunks four nerves, to the series.

(*a*) **Anterior Nerves,**—(1) External and (2) Internal anterior thoracic nerves. These are the nerves supplying the two pectoral muscles.

The **external anterior thoracic nerve** is derived from the "outer" cord, and receives contributory roots from the fifth, sixth, and seventh cervical nerves. The **internal anterior thoracic nerve,** from the "inner" cord, receives its roots from the eighth cervical and first thoracic nerves (Fig. 16).

Each nerve supplies both muscles. The pectoralis major is supplied by fibres which have a numerical sequence. The most cephalic fibres of the muscles are supplied by the highest, and the most caudal fibres by the lowest nerves in the series.

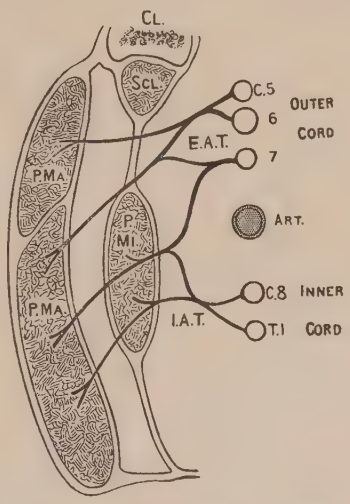


FIG. 16.—Innervation of the Pectoral Muscles.

The two nerves form a loop of communication over the axillary artery, from which branches pass to the pectoralis minor, after piercing which they end in the pectoralis major.

(*b*) **Posterior Nerves.**—Four collateral branches arise in the axilla from the "posterior" cord,—the circumflex, and the short, lower, and long subscapular nerves.

(3) **The circumflex nerve** is formed by the fifth and sixth cervical nerves. Enclosed at first in a sheath common to it and the musculo-spiral nerve, it becomes separate at the outer border of the subscapularis muscle. Accompanied by the posterior circumflex artery the nerve winds round the surgical neck of the humerus, in a quadrilateral

space, bounded by the humerus and scapular head of the triceps, the subscapularis, and teres major muscles, Reaching the outer side of the arm, under cover of the deltoid, it ends by supplying that muscle.

The circumflex nerve gives off three branches in the following order:

(*a*) A small branch to the shoulder joint.

(*b*) A nerve to the teres minor muscle, characterised by the possession of a fibrous ganglionic enlargement.

(*c*) A considerable cutaneous branch, which sweeps round the posterior border of the deltoid muscle, at the junction of its middle and lower thirds, and supplies the skin of the lower part of the deltoid region, and the outer side of the upper arm (Fig. 17).

(4) **Short Subscapular Nerves.**—There are usually two short subscapular nerves, closely associated, in their origin from the back of the fifth and sixth cervical nerves, with the origin of the circumflex. They innervate the higher part of the subscapularis muscle.

(5) **Lower Subscapular Nerve.**—This nerve is also closely associated with the origin of the circumflex, and is derived from the fifth and sixth cervical nerves. It accompanies the subscapular artery in a part of its course, and is the most external of the subscapular nerves. It is intermediate in length between the short and long subscapular nerves. It is distributed to the lower fibres of the subscapularis, and to the teres major muscle.

(6) **Long Subscapular Nerve.**—This nerve is closely associated at its origin with the origin of the musculo-spiral nerve. It arises as a rule from the sixth and seventh, or sixth, seventh, and eighth cervical nerves, and it is distributed to the latissimus dorsi muscle.

Distribution of the Nerves to the Upper Limb

As already stated, there are two series of nerves of distribution to the upper limb—terminal branches of the brachial plexus—one anterior, the other posterior.

The anterior nerves, derived from anterior trunks of the component nerves, through the "outer" and "inner" cords, comprise the musculo-cutaneous, median, ulnar, internal cutaneous, and lesser internal cutaneous nerves—

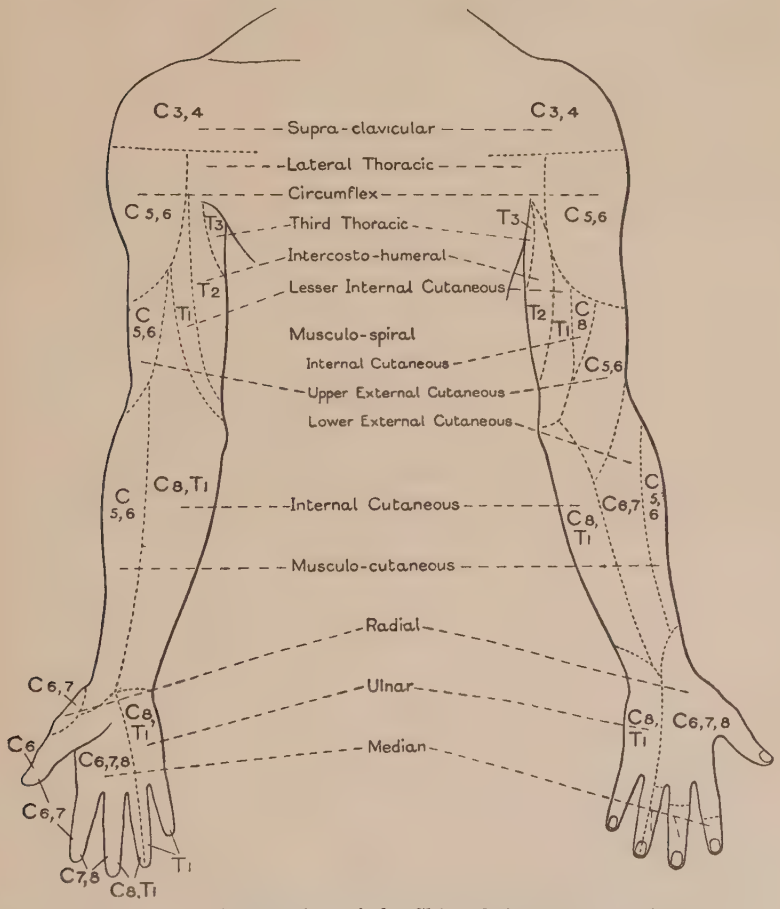


Fig. 17.—Innervation of the Skin of the Upper Limb.

destined for the innervation of the *front* of the arm, forearm, and hand.

The posterior trunk is the musculo-spiral, which arises from the posterior trunks of the last four cervical nerves, and is distributed to the *back* of the arm, forearm, and hand.

(The notable exception to this statement is the dorsal branch of the ulnar nerve, which is distributed to the back of the hand and fingers.)

(*a*) **Anterior Nerves.**—The **musculo-cutaneous nerve** (Fig. 18) takes origin from the fifth and sixth cervical nerves through the "outer" cord of the brachial plexus. Incorporated with it is a branch from the seventh cervical nerve, which is destined to supply the coraco-brachialis muscle (Herringham).

The nerve lies at first, with the outer head of the median, external to the axillary artery. Piercing obliquely the coraco-brachialis muscle (the nerve to which enters the muscle before it is pierced by the nerve), it next lies between the biceps and brachialis anticus. It supplies branches to each head of the biceps and to the brachialis anticus. It becomes superficial at the bend of the elbow, appearing at the outer border of the biceps muscle. Passing through the deep fascia it becomes cutaneous, and at once divides into two branches—anterior and posterior. The **anterior branch** supplies the skin of the front of the forearm from the elbow to the wrist, including the upper part of the ball of the thumb. The **posterior branch** supplies the skin of the back of the forearm on the outer side, in the upper two-thirds. The musculo-cutaneous often communicates with the median nerve in the upper arm beneath the biceps (Fig. 17).[1]

The Median Nerve (Fig. 15) takes origin by two heads, an **outer head** derived from the sixth and seventh cervical nerves through the "outer" cord, and an **inner head** derived from the eighth cervical and first thoracic nerves through the "inner" cord. The outer head is placed external to the axillary artery; the inner head crosses over the vessel obliquely. Thus formed, the nerve passes

[1] This communication may be from either nerve to the other. In some cases a branch from the musculo-cutaneous is carried down in the median to separate in the lower part of the arm as a nerve to the Brachialis Anticus. In other cases a branch from the median joins the musculo-cutaneous after its muscular branches have arisen.

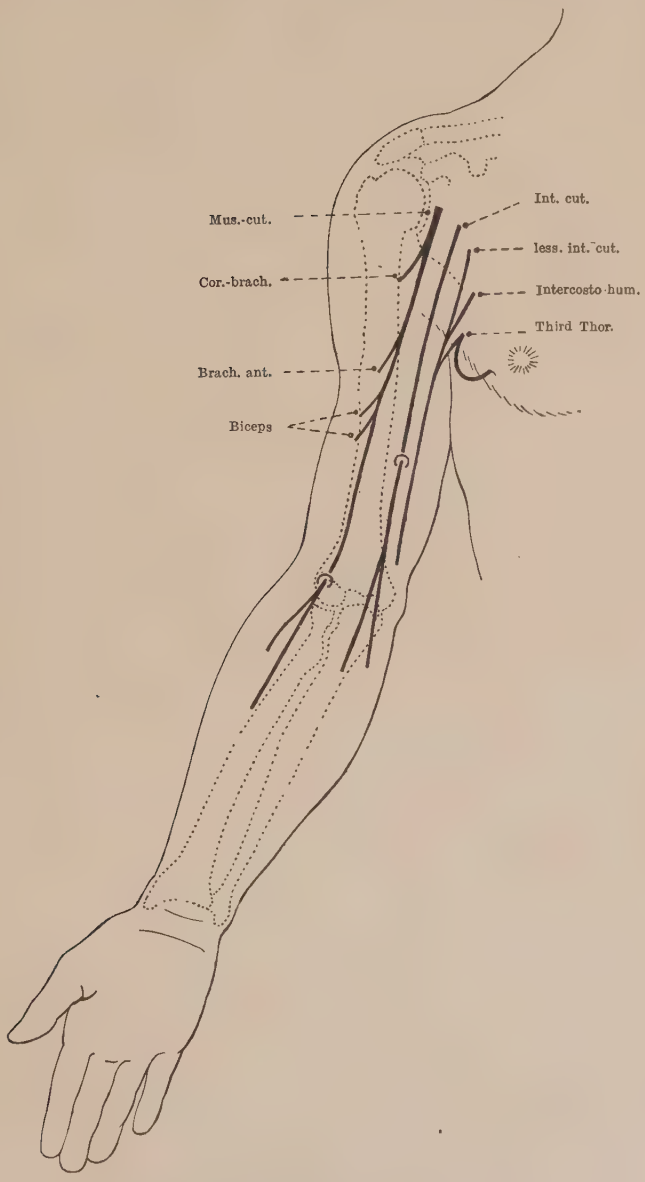


FIG. 18.—Distribution of Musculo-cutaneous, Internal Cutaneous, and Intercosto-humeral Nerves.

down through the upper arm in close relation to the brachial artery. In the upper half of the arm it is external to the artery. In the lower half it crosses over the artery obliquely, so as to be ultimately on its inner side.

In the hollow of the elbow it is placed on the inner side of the artery.

It proceeds straight down the middle of the forearm, lying deeply in its whole course. It first passes between the two heads of the pronator radii teres, separated at this stage from the ulnar artery by the deep head of the muscle. Thereafter it proceeds downwards between the flexor sublimis digitorum and the deep muscles of the forearm to the wrist. In the lower fourth of the forearm the nerve is situated immediately behind the tendon of the palmaris longus muscle, external to the tendons of the flexor sublimis digitorum.

In the forearm it is accompanied by an artery of variable size—the *comes nervi mediani.* At the wrist it passes beneath the anterior annular ligament, enveloped by the synovial sheath which surrounds the flexor tendons. Reaching the palm of the hand it separates into its terminal branches for the supply of the skin of the fingers and thumb, and of certain muscles of the thumb.

Branches (Fig. 19)

A. In the Arm

The median nerve gives off no branches in the arm (except the occasional communication with the musculocutaneous nerve already mentioned).

B. In the Forearm

(1) **Muscular Branches.**—The median nerve supplies in the upper part of the forearm the following muscles: Pronator radii teres, flexor carpi radialis, palmaris longus, and flexor sublimis digitorum. A second branch to the flexor sublimis digitorum is given off in the middle third of the forearm.

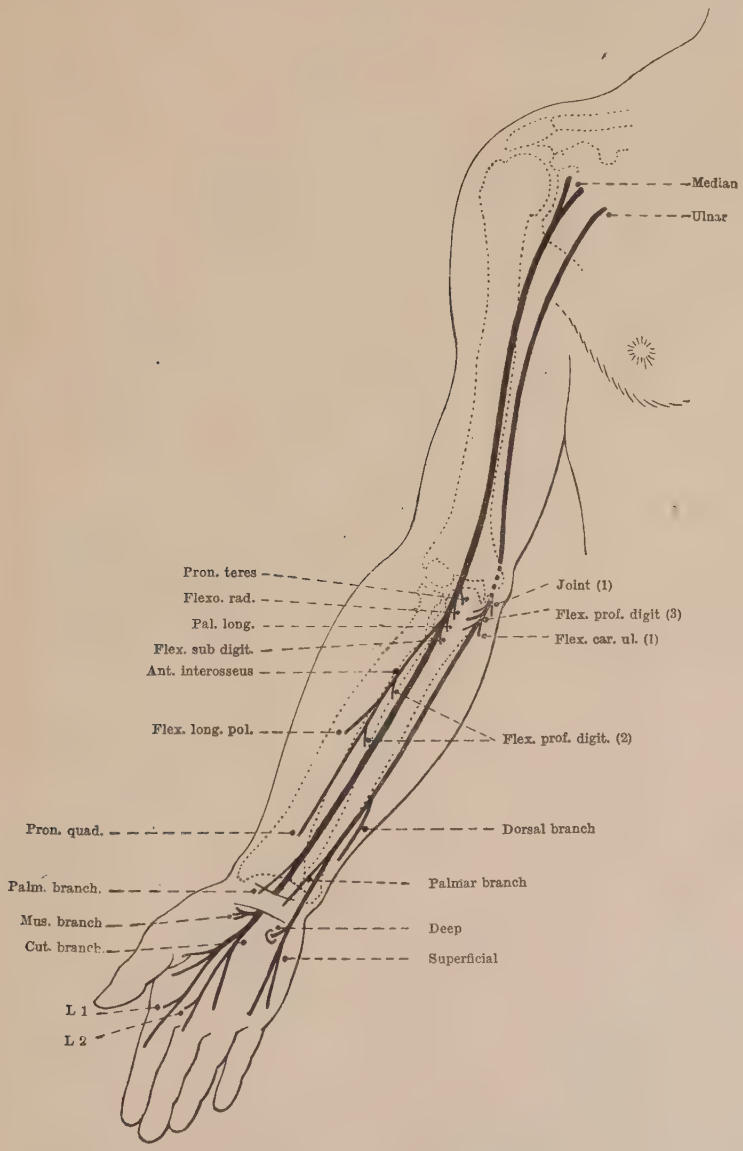


FIG. 19.—Distribution of the Median and Ulnar Nerves.

Anterior Interosseous Nerve.—This nerve arises from the median in the upper third of the forearm, and courses downwards on the interosseous membrane between the flexor longus pollicis and flexor profundus digitorum, accompanied by the anterior interosseous artery. It supplies these muscles, and terminates by entering the posterior surface of the pronator quadratus. It also supplies twigs to the wrist joint.

(2) A **Palmar Cutaneous Branch** arises in the lower third of the forearm, and piercing the fascia above the anterior annular ligament, supplies the skin of the palm of the hand.

(3) A communication between the median and ulnar nerves is frequently found in the forearm.[1]

C. In the Hand

(1) **Muscular Branch.**—Immediately below the lower border of the anterior annular ligament, a short muscular trunk is given off, which is directed outwards superficially to the muscles of the thumb. It supplies the abductor pollicis, opponens pollicis, and flexor brevis pollicis.

(2) **Cutaneous Branches.**—The terminal branches of the nerve are five cutaneous trunks, which pass downwards between the palmar arch and the long flexor tendons to supply (1) and (2) each side of the thumb, (3) the radial side of the index finger and the first lumbrical muscle, (4) the adjacent sides of the index and middle fingers and the second lumbrical muscle, and (5) the adjacent sides of the middle and ring fingers.

The cutaneous branches to the index, middle, and ring fingers supply branches which are distributed also to the dorsal aspects of these fingers (Fig. 17).

The **Ulnar Nerve** (Fig. 15) takes origin through the

[1] This occurs about four inches below the internal condyle, and is said to be composed of fibres from the ulnar to the median nerve, reinforcing the branches of the latter nerve to the parts of the flexor sublimis digitorum which are associated with the tendons to the 3rd, 4th, and 5th fingers. Thus after division of the median nerve there may still be retained power of movement in these digits.

" inner " cord of the plexus, from the eighth cervical and first thoracic nerves. (It occasionally receives an additional root from the seventh nerve through the " outer " cord.)

In the axilla it lies on the inner side of the axillary artery, with the other nerves derived from the " inner " cord.

In the arm the nerve courses downwards at first on the inner side of the brachial vessels. At the middle of the arm it recedes from the artery, and passing over the edge of the internal intermuscular septum, it continues its course behind the septum and in front of the triceps muscle to the elbow. After passing behind the internal condyle of the humerus, where it is to be felt as " the funny bone," it enters the forearm between the two heads of the flexor carpi ulnaris. In the forearm the nerve passes down on its inner side between the flexor carpi ulnaris and flexor profundus digitorum to the wrist. It joins the ulnar artery in the middle third of its course, and continues onwards on its inner side.

At the wrist, just above the anterior annular ligament, the ulnar nerve and artery pierce the deep fascia, and lie on the anterior annular ligament external to the pisiform bone. They are protected in this situation by a strong band of fascia, which passes from the pisiform bone to the annular ligament.

The nerve divides below the ligament into its terminal branches—superficial and deep—for the supply of the skin and muscles of the hand.

The ulnar nerve gives off no branches in the arm.

At the elbow it supplies an articular branch to the elbow joint.

In the Forearm (Fig. 19).—Just below the elbow **two muscular branches** arise, to supply the flexor carpi ulnaris and the inner half of the flexor profundus digitorum muscles. (Occasionally a third muscular branch is given off to the flexor sublimis digitorum.)

Two cutaneous branches arise in the forearm.

The **dorsal branch** is given off in the middle third, and

passing downwards and backwards behind the flexor carpi ulnaris, becomes cutaneous in the lower third of the back of the forearm. Passing over the posterior annular ligament the nerve is distributed on the back of the hand and fingers, supplying the back of the little finger in its whole length, and the inner half of the ring finger (Fig. 17).

It supplies in some cases the whole of the back of the ring finger. It communicates with the radial nerve on the back of the hand.

The palmar branch is a minute filament which arises from the ulnar nerve in the lower third of the forearm. It supplies the palm of the hand after passing through the deep fascia and over the anterior annular ligament. It communicates with the palmar branch of the median nerve.

There is frequently a contribution from the median to the ulnar nerve in the forearm.

The Ulnar Nerve in the Hand.—As already stated the ulnar nerve divides in the palm into its terminal branches, superficial and deep.

The **superficial branch** supplies twigs to the palmaris brevis muscle and to the skin of the inner part of the palm, and ends by dividing into two digital branches, inner and outer. The inner branch pierces the deep fascia near the middle of the inner border of the palm, and supplies the inner side of the little finger. The outer branch pierces the deep fascia in the cleft between the ring and little fingers, and divides into two collateral branches for the supply of the adjacent sides of the little and ring fingers (Fig. 17).

The **deep branch** passes through the origins of the muscles of the little finger, and is situated along with the deep palmar arch, deep in the palm upon the interosseous muscles. It is entirely muscular in its distribution, and supplies the following muscles: the inner two lumbrical muscles, the abductor, opponens, and flexor brevis minimi digiti, all the palmar and dorsal interosseous muscles, the adductor pollicis, and interosseus primus volaris (Henle).

The dorsal branch of the ulnar nerve has been referred

to already as an anomalous nerve. Here is a nerve, derived from a combination of **anterior** trunks and formed from both eighth cervical and first thoracic nerves, supplying branches almost entirely to the muscles and skin of the **anterior** aspect of the limb, yet giving off a large branch for the skin of the back of the hand and fingers. It is difficult to explain the anomaly. Possibly the nerve represents the posterior trunk of the first thoracic nerve, which instead of separating like the others in the axilla is carried down to the forearm, incorporated with the ulnar nerve.

The **Internal Cutaneous Nerve** (Fig. 15) is also derived from the eighth cervical and first thoracic nerves through the "inner" cord of the plexus. It lies at first on the inner side of the axillary artery, with the ulnar and the inner head of the median nerve. In the upper half of the arm the nerve is anterior to the brachial artery. At the middle of the arm on the inner side there is a perforation in the deep fascia through which the basilic vein passes to join the brachial veins, and out of which the internal cutaneous nerve emerges to become cutaneous. After becoming superficial the nerve supplies twigs to the skin of the upper arm, and above the elbow divides into anterior and internal branches, for the forearm. The anterior branch supplies the skin of the front of the forearm down to the wrist. The internal branch supplies the skin of the back of the forearm on the inner side in the upper two-thirds (Figs. 17 and 18).

The **Lesser Internal Cutaneous Nerve** (Fig. 15) can be traced through the "inner" cord of the brachial plexus to the first thoracic nerve. It becomes superficial as a rule at the posterior axillary fold, where it joins and becomes more or less incorporated with the intercosto-humeral nerve. In some cases it joins the intercosto-humeral nerve in the axillary space. As already stated (p. 27) the intercosto-humeral nerve is also joined by the posterior trunk of the lateral branch of the third intercostal nerve, so that a strip of skin from the axilla to a point midway

between the internal condyle of the humerus and the olecranon process is innervated by the first three thoracic nerves (Figs. 17 and 18).

The lesser internal cutaneous nerve probably represents the lateral branch of the first thoracic nerve.

The **Musculo-spiral Nerve** (Fig. 15) is derived from the posterior trunks of the anterior primary divisions of the last four cervical nerves. (In some cases it receives a minute filament from the back of the first thoracic nerve.) It forms the continuation of the "posterior" cord of the plexus into the arm, and is distributed to the back of the arm, forearm, and hand.

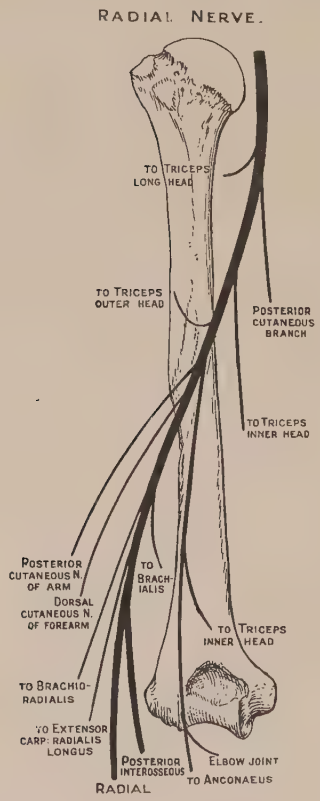


FIG. 20.—Scheme of the Musculo-spiral Nerve.

The nerve lies at first behind the axillary artery. Proceeding to the arm it is placed in the upper third on the inner side of the humerus and behind the brachial artery. In the middle third it winds round the back of the bone in the spiral groove between the triceps and the humerus, accompanied by the superior profunda artery. In the lower third of the arm it is external to the humerus. Piercing the external intermuscular septum, it passes downwards, lying deeply between the brachio-radialis and brachialis anticus muscles. It terminates in front of the external condyle of the humerus by dividing into the radial and posterior interosseous nerves (Fig. 20).

The collateral branches of the musculo-spiral nerve are in three sets:

(*a*) Three branches arising on the inner side of the arm:

(1) An **internal cutaneous** branch, distributed to the skin of the arm behind the area supplied by the intercosto-humeral nerve (Fig. 17);

(2) A muscular branch to the **long head of the triceps;** and

(3) A muscular branch to the **inner head of the triceps.** This nerve accompanies the ulnar nerve in part of its course, and is known as the **ulnar collateral** (Krause).

(*b*) Three series of nerves arising on the back of the arm, while the nerve occupies the spiral groove:

(1) A muscular branch to the **outer head of the triceps;**

(2) A muscular branch to the **inner head of the triceps** (and **anconeus**), which also supplies the elbow joint; and

(3) The **external cutaneous branches.**

These are two in number: **superior,** smaller, supplying the skin over the lower half of the back of the arm, and the back of the elbow joint; and **inferior,** larger, supplying the skin of the back of the arm in its lower third and the skin of the back of the forearm in its upper two thirds (Fig. 17).

(*c*) Three muscular branches arise on the outer side of the arm—for the **brachio-radialis, extensor carpi radialis longior,** and **brachialis anticus** (Figs. 20 and 21).

The nerve to the brachialis anticus muscle is not always present. It is anomalous in character, representing a nerve with a "dorsal" origin, innervating a muscle which is "ventral" in character. The main nerve to the muscle is derived from the musculo-cutaneous nerve. It is well known that a frequent fusion of the brachio-radialis and brachialis anticus takes place over the musculo-spiral nerve in this part of its course. It may be that the nerve in question is supplied to fibres of the brachio-radialis which have been incorporated with the brachialis anticus.

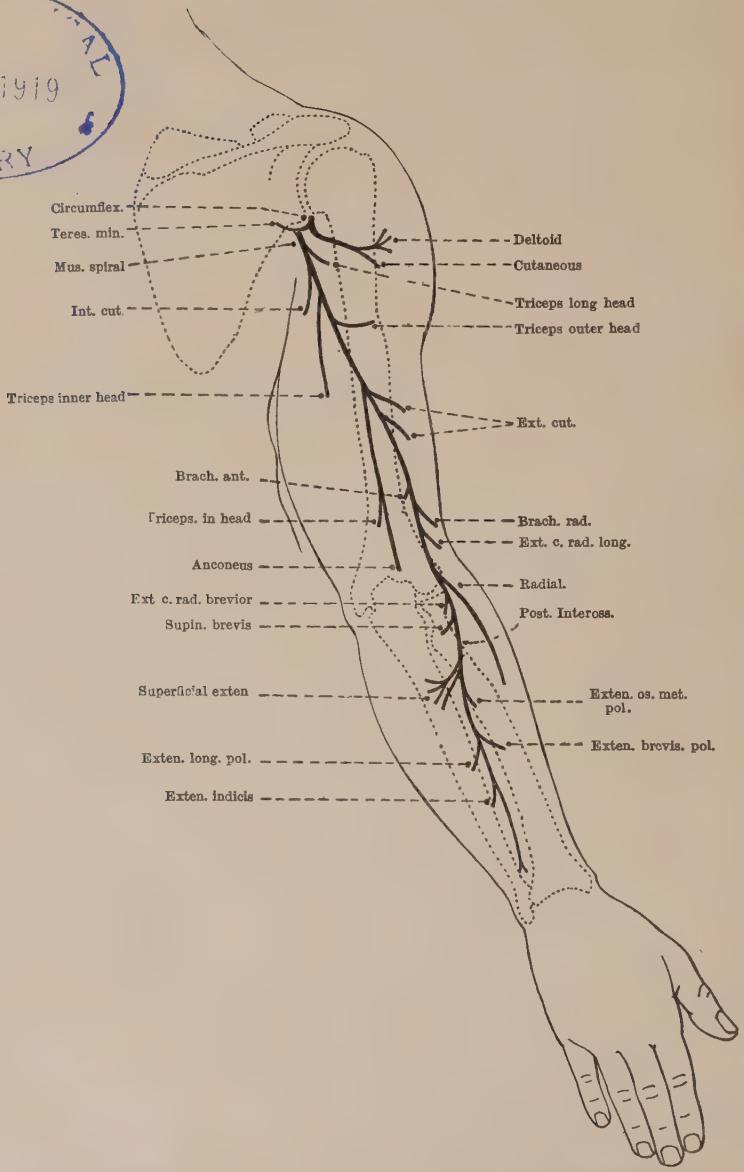


FIG. 21.—Scheme of Distribution of Branches of Musculo-spiral Nerve.

Terminal Branches of the Musculo-Spiral Nerve

The **Radial Nerve** proceeds down the front of the forearm on the outer side under cover of the brachio-radialis muscle. At the junction of the upper and middle thirds of the forearm it meets with the radial artery, which it accompanies—lying on the outer side of the artery—in the middle third. At the junction of the middle and lower thirds of the forearm the nerve is directed obliquely downwards and backwards, passes beneath the tendon of the brachio-radialis, and becomes cutaneous on the back of the forearm.

The radial is a purely cutaneous nerve. It is distributed to the back of the lower third of the forearm and the back of the hand and fingers in a somewhat variable way. It divides into branches, which as a rule innervate two-thirds of the back of the hand on the outer side, and send branches over the outer part of the ball of the thumb. It supplies the whole dorsum of the thumb, the skin over the proximal phalanx of the fore finger, and part of the proximal phalanx of the middle finger (Fig. 17). The areas of skin between the proximal phalanges of the middle and ring fingers may be supplied by the radial or by the dorsal branch of the ulnar nerve.

In many instances the area supplied is less than that indicated. On the other hand cases are recorded in which the radial nerve supplies the whole of the back of the hand and fingers.

The **Posterior Interosseous Nerve** is chiefly muscular in distribution. Proceeding downwards on the front of the upper part of the forearm on the outer side, under cover of the brachio-radialis muscle, the nerve pierces the supinator brevis muscle, and, sweeping round the shaft of the radius, appears in the upper third of the back of the forearm.

Occupying at first a position on the back of the forearm beneath the origins of the superficial extensor muscles, it lies successively on the supinator brevis

and extensor ossis metacarpi pollicis. It then passes beneath the extensor longus pollicis, and continues its course on the interosseous membrane. It finally ends

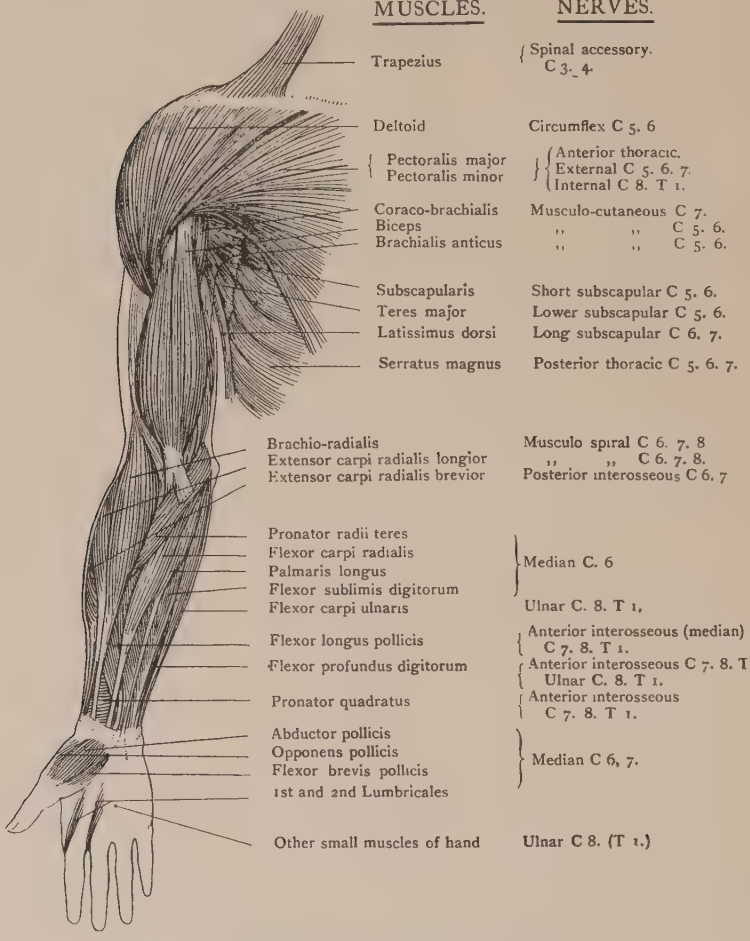


FIG. 22.—Innervation of the Muscles of the Upper Limb. Front of the Limb.

by passing as a minute nerve over the back of the lower end of the radius to supply the radio-carpal and inter-carpal joints. In the middle third of the back of the

forearm the nerve is accompanied by the posterior interosseous artery.

The collateral branches of the posterior interosseous nerve

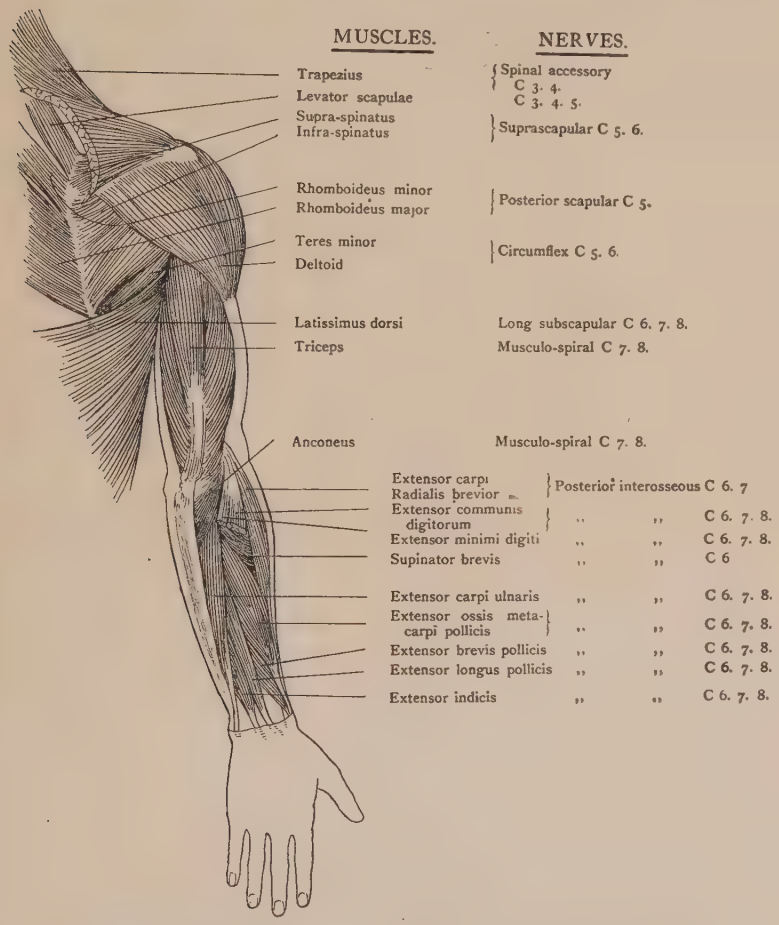


FIG. 23.—Innervation of the Muscles of the Upper Limb. Back of the Limb.

are in two sets. Before the nerve pierces the supinator brevis it supplies branches to two muscles—**extensor carpi radialis brevior** and **supinator brevis.** Immediately after

appearing on the back of the forearm the nerve supplies a bundle of branches for the **extensor longus digitorum, extensor minimi digiti,** and **extensor carpi ulnaris.** Proceeding onwards the nerve supplies branches to the **extensor ossis metacarpi pollicis, extensor longus pollicis, extensor brevis pollicis,** and **extensor indicis.**

Cases are on record in which the posterior interosseous nerve has given rise to a cutaneous branch for the skin of the adjacent sides of the fore and middle fingers.

The Lumbo-sacral Plexus

In many animals the lumbo-sacral plexus for the formation of nerves of distribution to the lower limb is separate and distinct from the pudendal plexus, destined for the perineum and caudal region. The nerve of junction which may contribute to both plexuses is sometimes known as the *nervus bigeminus*.

In man, however, there is no distinct differentiation, and the nerves of the lumbo-sacral and pudendal plexuses overlap at their origins.

For the purposes of convenience and lucidity, however, it is best to describe the two plexuses separately.

The lumbo-sacral plexus is primarily the plexus for the provision of nerves of distribution to the lower limb. While most of the nerves entering into its composition are distributed wholly to the limb, those at the cephalic and caudal ends of the series (first lumbar and second and third sacral) are distributed to the trunk as well.

The plexus is formed by the anterior primary divisions of all the lumbar nerves, and of the first three sacral nerves. It is separated by the sacro-iliac articulation into two parts, lumbar and sacral. The nerve of junction, entering into the formation of both portions, is the fourth lumbar nerve; in mammals, as a general rule, the penultimate lumbar nerve. This nerve is sometimes called the *nervus furcalis* (Fig. 24).

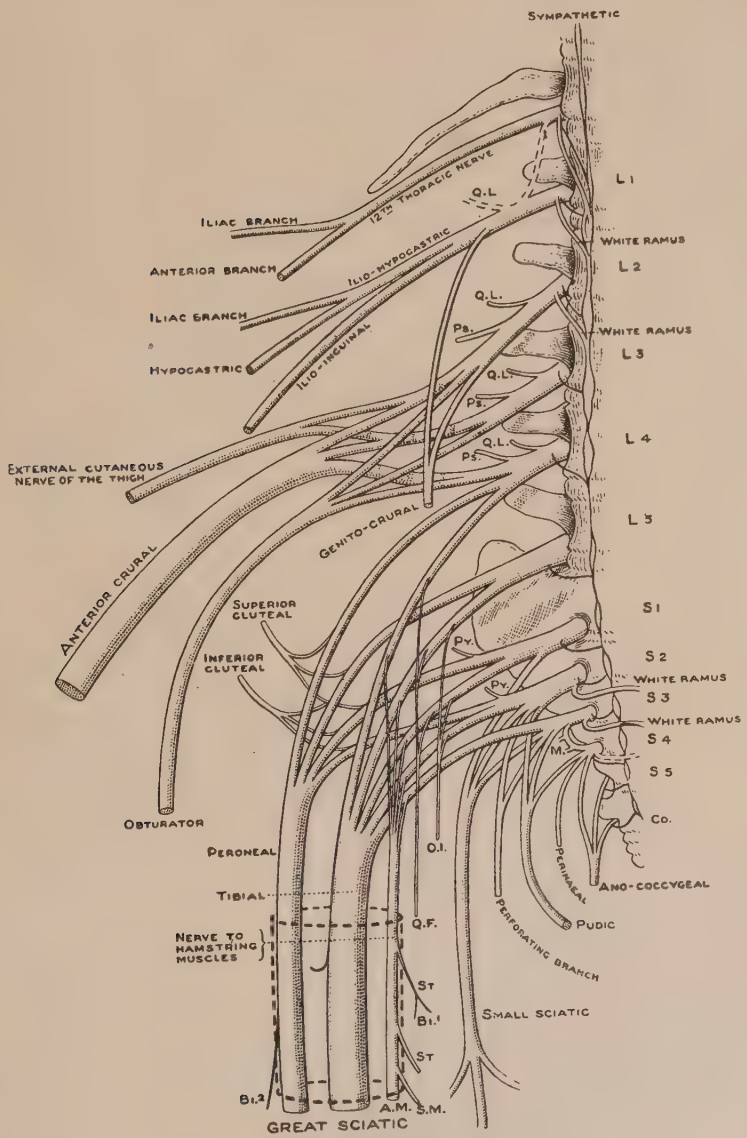


FIG. 24.—The Lumbo-sacral Plexus.

In cases in which by the attachment of the limb to the spine at a lower level than usual, and the liberation of the first sacral vertebra to form an additional (sixth) lumbar vertebra, the plexus also is often placed at a lower level, and the fifth lumbar nerve may be the *nervus furcalis*.

Lumbar Part of the Plexus.

The **lumbar** part of the plexus is formed in the substance of the psoas muscle, from which its nerves of distribution emerge on the posterior abdominal wall (Fig. 25).

The nerves which enter into its formation are the anterior primary divisions of the first three lumbar nerves and a part of the fourth, with sometimes a communication from the twelfth thoracic nerve.

The nerves of the plexus are collateral and terminal. The **collateral branches** are given off from the separate spinal nerves to the following muscles:

Quadratus lumborum	(L 1, 2, 3.(4))
Psoas magnus	(L (1), 2, 3 (4))
Psoas parvus	(L 1 or 2)

The **terminal branches** of distribution are the following:

Ilio-hypogastric	(L 1)
Ilio-inguinal	(L 1)
Genito-crural	(L 1, 2)
External cutaneous	(L 2, 3)
Obturator	(L 2, 3, 4)
Anterior crural	(L 2, 3, 4)

The **ilio-hypogastric** and **ilio-inguinal** nerves, derived from the first lumbar nerve with an occasional contribution from the twelfth thoracic, resemble in their course and distribution the lower thoracic nerves.

The **ilio-hypogastric nerve** emerges from the outer border of the psoas magnus muscle, and traverses the post-

erior abdominal wall, lying on the quadratus lumborum muscle. Piercing the transversalis abdominis muscle, it proceeds downwards and forwards between it and the obliquus internus to a point in front of the anterior superior

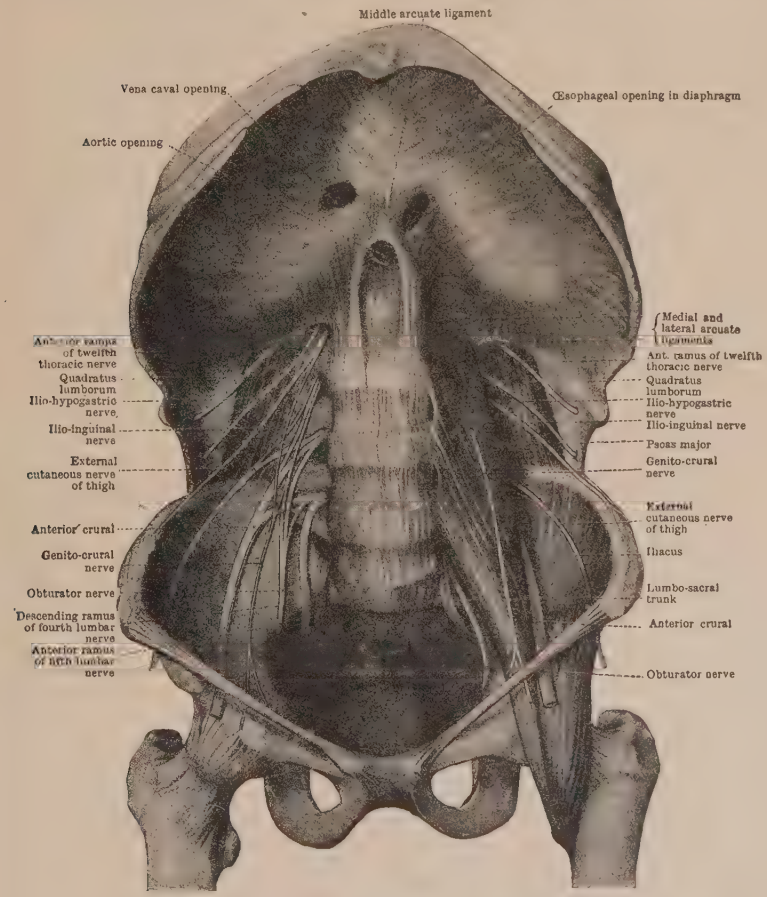


FIG. 25.—The Muscles and Nerves on the Posterior Abdominal Wall.

spine. Here it pierces the obliquus internus muscle, and proceeds onwards under cover of the aponeurosis of the obliquus externus. Piercing this about one and a half inches from the crest of the pubis, it ends by supplying

the skin of the lower part of the abdominal wall. This nerve supplies muscular branches to the muscles between which it lies, and gives off a lateral (iliac) branch of small size, which passes over the iliac crest to supply a small area of the skin of the buttock (Figs. 25 and 26).

The **ilio-inguinal nerve** has a somewhat similar course and distribution, but it gives off no lateral branch. Arising with the ilio-hypogastric nerve, it has a similar course, at a lower level, as far as the anterior abdominal wall. Here it pierces the internal oblique muscle below and in front of the ilio-hypogastric nerve, and proceeds downwards and forwards between the aponeurosis of the obliquus externus and the cremaster muscle. It becomes cutaneous by passing through the external abdominal ring, and is finally distributed to the skin over the pubis, to the root of the penis, the base of the scrotum, and the inner part of Scarpa's triangle (Fig. 26).

The remaining nerves belonging to the lumbar portion of the plexus are four in number:

Genito-crural and **obturator**, which are anterior or ventral in origin and distribution, and **external cutaneous** and **anterior crural**, which are posterior or dorsal.

The **genito-crural nerve** is formed in the substance of the psoas muscle by the union of two slender roots from the front of the first and second lumbar nerves. Piercing the psoas muscle the nerve passes down to the groin, where it divides into **crural** and **genital** branches (Fig. 25).

The **crural** branch passes beneath Poupart's ligament on the outer side of the femoral artery, to which it supplies small twigs, and piercing the fascia lata external to the saphenous opening, it supplies the skin over the outer part of Scarpa's triangle.

The **genital** branch passes obliquely downwards and forwards into the inguinal canal, and supplies the cremaster muscle.

The **external cutaneous nerve** arises by two roots from the back of the trunks of the second and third lumbar nerves

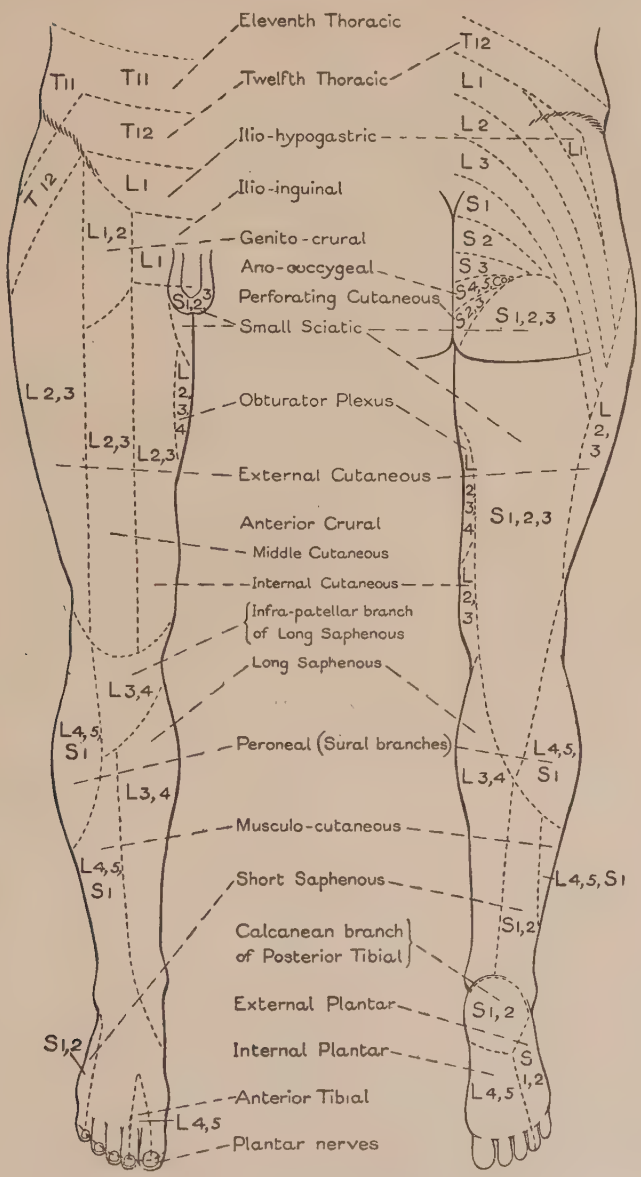


FIG. 26.—Innervation of the Skin of the Lower Limb.

(Fig. 24). It is a considerable nerve, which pierces the outer border of the psoas magnus muscle about its middle. Sweeping across the iliacus muscle, it passes beneath Poupart's ligament just below the anterior superior iliac spine, and passes over, under, or through the sartorius muscle, near its origin. It occupies a sheath of fascia lata for four or five inches on the outer side of the thigh in its upper fourth before finally becoming cutaneous. It divides into **anterior** and **posterior** trunks for the supply of the skin on the front and outer side of the thigh in its whole extent (Fig. 26).

The **Obturator** and **Anterior Crural** nerves are closely associated at their origins, and are distinctly comparable to nerves of the brachial plexus, arising respectively from "anterior" and "posterior" cords. The main parts of the anterior primary divisions of the second and third lumbar nerves, and the part of the fourth engaged in the formation of the lumbar part of the plexus, subdivide in the substance of the psoas magnus into anterior or ventral and posterior or dorsal branches. The anterior trunks of the nerves combine to form the obturator. The posterior trunks give rise to the anterior crural nerve (Fig. 24).

They correspond in a similar way in their distribution. The obturator supplies the adductor muscles and the skin of the inner side of the thigh—parts which are primitively ventral in position. The anterior crural supplies muscles and skin on the front of the thigh—parts which are primitively dorsal in position.

The **Obturator Nerve** passes vertically downwards in the substance of the psoas magnus, from the inner border of which it emerges at the pelvic brim. Passing external to the internal iliac vessels and the ureter, and lying in the extra-peritoneal tissue, accompanied by the obturator artery it enters the thigh through the obturator groove. In the groove it divides into two branches—superficial and deep (Fig. 27). The **superficial branch** passes in front of the obturator externus and adductor brevis muscles, and

behind the pectineus and adductor longus. It finally subdivides at the inner border of the adductor longus into its terminal branches, of which one supplies the femoral artery and the other, passing between the sartorius and gracilis, ends by supplying the skin of the inner side of the thigh in its middle third. This branch joins the **obturator plexus,** formed by its union with twigs from the internal

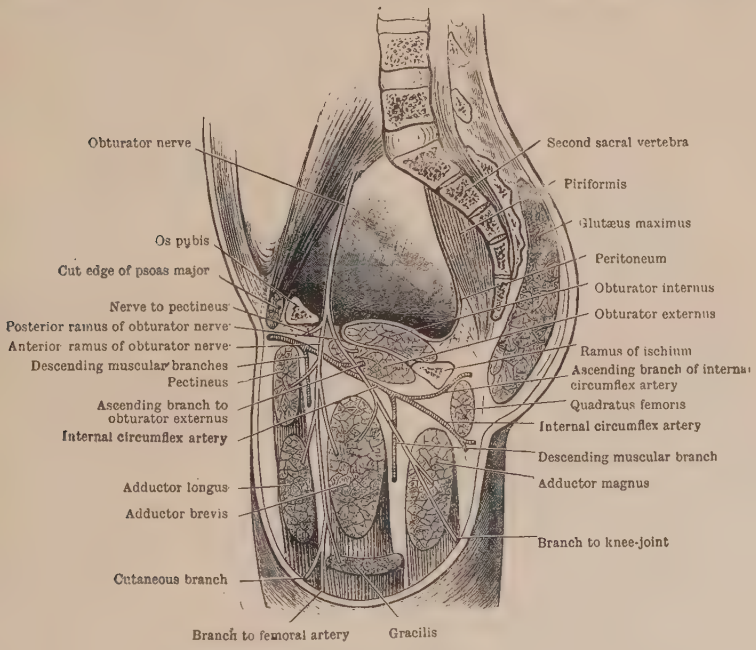


Fig. 27.—Scheme of the Distribution of the Obturator Nerve.

cutaneous and internal saphenous branches of the anterior crural nerve (Fig. 26).

The **collateral branches** of the superficial part of the obturator nerve supply the hip joint, the **adductor longus,** and **gracilis,** and sometimes the **pectineus** and the **adductor brevis** muscles.

The **deep part of the obturator nerve** enters the thigh after piercing the obturator externus muscle. It passes

down the thigh, between the adductor brevis and adductor magnus muscles, and after piercing the latter muscle it applies itself to the popliteal artery, and ends as an articular (geniculate) branch for the knee joint.

Its **collateral branches** are the nerve to the **obturator**

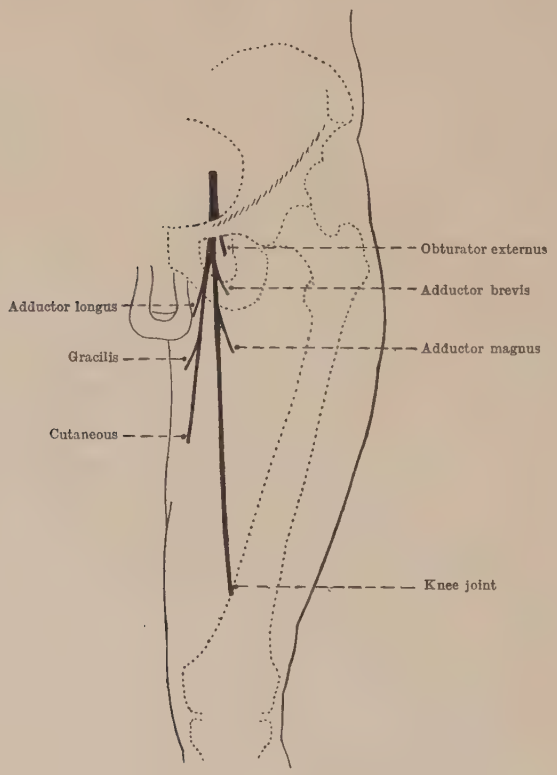


FIG. 28.—Obturator Nerve.

externus muscle (which arises before the nerve pierces the muscle), and muscular branches to the **adductor magnus** and **adductor brevis** (if this muscle is not innervated by the superficial part of the nerve) (Fig. 28).

The **Anterior Crural Nerve** (Fig. 24) is the largest nerve of this series. Formed in the substance of the psoas

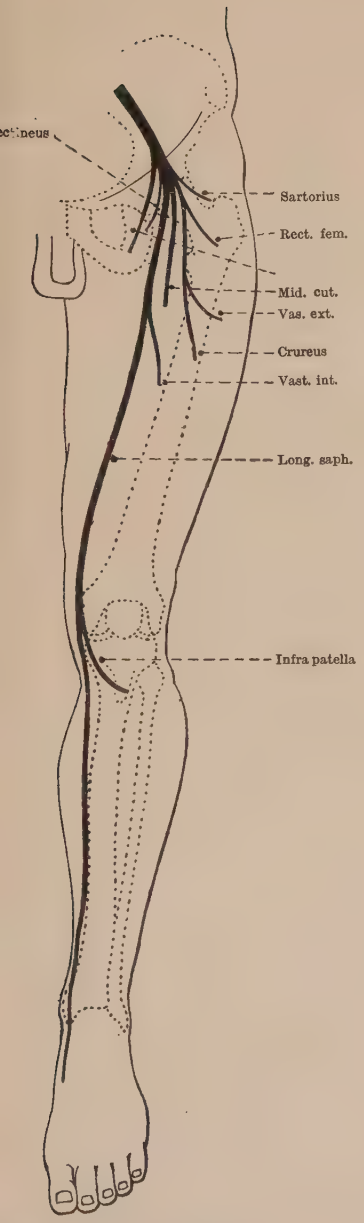


FIG. 29.—Distribution of Anterior Crural Nerve.

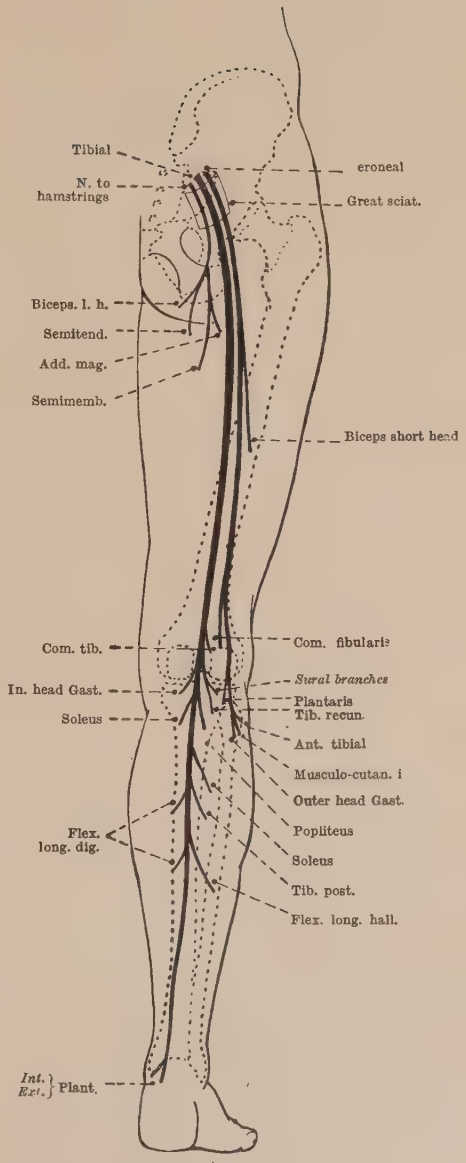


FIG. 30.—Great Sciatic Nerve.

magnus by the union of the posterior trunks of the anterior primary divisions of the second, third, and fourth lumbar nerves, it extends obliquely downwards and outwards through the muscle to its outer border, from which it emerges in the false pelvis in a groove between the psoas and iliacus muscles. Passing into the thigh beneath Poupart's ligament it divides in Scarpa's triangle into a sheaf of branches, for the supply of the skin and muscles of the lower limb. In the thigh it lies external to the femoral vessels, and outside the femoral sheath. The external circumflex artery passes outwards among the branches of the nerve near their origins.

The branches of the anterior crural nerve (Fig. 29) are articular, muscular, and cutaneous. **Articular branches** are supplied to the hip joint directly, and through the nerves to the vastus internus muscle, to the knee joint. **Muscular branches** supply the iliacus, sartorius, pectineus, and quadriceps extensor—rectus femoris, vastus externus, vastus internus, crureus, and subcrureus. The nerve to the pectineus passes inwards behind the femoral vessels. It is usually the only nerve to this muscle. Occasionally a small nerve enters the muscle from behind—a branch of the superficial part of the obturator nerve. The occurrence of this nerve is associated with the inclusion in the pectineus muscle of a part of the adductor muscular mass.

The **cutaneous branches** are the following (Figs. 26 and 29):

(*a*) **Two middle cutaneous nerves.**—These pierce the deep fascia in the upper third of the front of the thigh, after passing over or through the sartorius muscle. They innervate the skin of the front of the thigh down to the knee.

(*b*) There are usually **three internal cutaneous nerves**—upper, middle, and lower. The upper branch pierces the deep fascia near the apex of Scarpa's triangle, and supplies the skin of the middle third of the thigh on the front and inner side. This nerve sends twigs to the *obturator plexus.*

The middle branch supplies the skin of the lower third of the thigh, while the lower branch, becoming superficial a short distance above the knee, supplies the skin of the inner side of the knee and leg.

(*c*) The **internal or long saphenous nerve** may be regarded as the terminal branch of the anterior crural nerve. It courses downwards through Scarpa's triangle, lying external to the femoral vessels. It crosses the vessels in Hunter's canal, where it supplies a communication to the *obturator plexus*, and passing between the sartorius and gracilis muscles in company with the superficial branch of the anastomatic artery, it becomes cutaneous at the inner side of the knee. It passes down the inner side of the leg in company with the internal saphenous vein, and going over the internal malleolus, terminates at the middle of the inner border of the foot.

The long saphenous nerve itself supplies the skin of the inner side of the leg in its whole extent, as well as the skin over the internal malleolus, and the inner side of the foot as far as the middle of the inner border (Fig. 26).

Before becoming cutaneous the nerve gives off a **patellar branch,** which pierces the sartorius muscle at the inner side of the knee, and sweeping over the inner tuberosity of the tibia supplies the skin of the upper part of the leg (Fig. 26).

Patellar Plexus.—Communications occur in front of the patella between the cutaneous branches of the external cutaneous, middle and internal cutaneous, and the patellar branch of the internal sapheous nerves.

Accessory Obturator Nerve.—This is a nerve which is only occasionally present. It arises from the roots of the anterior crural nerve (L. 3, 4). It passes into the thigh between Poupart's ligament in front and the pubis behind. It is usually distributed in the thigh in the form of three branches—one to the hip joint, one to the pectineus muscle, and one to communicate with the anterior crural nerve. Cases have been seen in which it was much larger, con-

tributing a large cutaneous branch to the inner side of the thigh, which communicates with the obturator plexus.

The Sacral Plexus

The sacral portion of plexus for the lower limb is formed by part of the fourth lumbar nerve (n. furcalis), the fifth lumbar, and first two sacral, and usually a considerable portion of the third sacral nerve. In a minority of cases the third sacral nerve does not participate, in which case the second sacral nerve is the n. bigeminus (Fig. 24).

General Survey (Fig. 24).—The contributory part of the fourth lumbar nerve pierces the psoas magnus muscle on its inner side, and joins the anterior primary division of the fifth lumbar nerve to form the so-called lumbo-sacral cord. This cord enters the pelvis in front of the lateral mass of the sacrum, and forms part of a broad band, the **great sciatic nerve,** which is completed by the addition of the anterior primary divisions of the first two and a part of the third sacral nerves. This band is formed in the pelvis in front of the pyriformis muscle. It enters the buttock, where it lies beneath the gluteus maximus, by passing through the great sciatic foramen below the pyriformis muscle. Passing below the edge of the gluteous maximus midway between the great trochanter of the femur and the ischial tuberosity, it occupies the back of the thigh, covered by the hamstring muscle. It gives off from its inner side in one or two bundles **the nerve to the hamstring muscles,** and divides at a variable point into **the external popliteal** or **peroneal** and the **internal popliteal** or **tibial** nerves.

In a freshly killed animal the nerve can be made out to consist of three essential parts lying side by side and bound together by a delicate connective tissue sheath—peroneal, tibial, and nerve to the hamstrings from without inwards.

Not infrequently the peroneal and tibial nerves are separate from their origin, being separated in the buttock

by a slip of the pyriformis, the peroneal nerve dividing the muscle into two parts.

While the nerve to the hamstring muscles has a closer connection than the peroneal with the tibial trunk, there is no doubt that these three nerves are separate and distinct in origin as in distribution.

The peroneal and tibial nerves separate from one another at a variable point. As already stated they may be separate from their origin, or the great sciatic nerve may divide at any point between the great sacro-sciatic foramen and the popliteal space. There is no interchange of fibres between the two nerves in any part of their course.

The **peroneal nerve,** when united with the tibial and the nerve to the hamstring muscles in the great sciatic trunk, can be readily separated and dissected up to its origin from the sacral plexus. If the ala of the sacrum and the corresponding part of the ilium (and sacro-iliac joint) be removed, the component elements of the different nerves can be followed up to the plexus. The **peroneal nerve** is found to be formed by the union of a series of trunks which come from the fourth and fifth lumbar and the first **two** sacral nerves. When the second sacral nerve is the last to enter into the formation of the great sciatic trunk the **first** sacral is the lowest in the composition of the peroneal trunk.

Each of the anterior primary divisions concerned divides into posterior or dorsal, and anterior or ventral trunks. The posterior or dorsal trunks unite to form the peroneal nerve, which thus corresponds to the musculo-spiral nerve of the upper limb and the anterior crural nerve of the lumbar part of the plexus for the lower limb. These trunks proceed a considerable way down the peroneal trunk before subdividing and reuniting with branches of neighbouring nerves to form the nerves of distribution associated with the peroneal.

The **tibial nerve** is formed by the union of the anterior or ventral trunks of the anterior primary divisions of the

fourth and fifth lumbar, and first two sacral nerves, with the addition of a part of the third sacral nerve (n. bigeminus) As already mentioned, there may be no contribution from the third sacral nerve. These component trunks lie ventral to the trunks forming the peroneal nerve, and can be traced for a considerable distance in the great sciatic trunk before subdividing and reuniting to form the nerves of distribution associated with the tibial nerve. This accounts for the so-called plexus described in the middle third of the great sciatic (or, more properly, tibial) nerve in the thigh. This plexus is due to the subdivision of these ventral or anterior trunks and their subsequent reunion with the branches of adjacent trunks to form the nerves of distribution.

The **nerve to the hamstring muscles**, lastly, has similar individuality in regard to its origin. Emerging as one or two bundles of nerves from the inner border of the great sciatic (or tibial) nerve, it forms a distinct trunk on the inner side of the nerve in the buttock. Traced up to the anterior primary divisions, it is found to take origin from all the nerves concerned in forming the tibial trunk—by roots which lie on the ventral or anterior aspect of the origins of the tibial nerve. These trunks pass down and subdivide and reunite to form the nerves for the supply of the individual muscles.

Distribution of the Nerves of the Sacral Part of the Plexus

Collateral Branches in the Buttock.—There are two series of collateral branches arising in the buttock.

(*a*) **Three Posterior (dorsal) Branches.**—(1) **Nerves to the Pyriformis Muscle** are two small branches arising from the dorsal aspect of the first and second sacral nerves, which enter the muscle separately.

(2) The **superior gluteal nerve** arises from the back of the posterior trunks of the fourth and fifth lumbar and the

first sacral nerve. It passes through the great sacro-sciatic foramen into the buttock, above the pyriformis muscle, in company with the gluteal artery. It is placed deeply beneath the glutei—maximus and medius,—and after supplying the glutei—medius and minimus—it passes forwards to terminate in the tensor fasciæ femoris muscle.

(3) The **inferior gluteal nerve** arises from the back of the posterior trunks of the fifth lumbar and first two sacral nerves. Appearing in the buttock below the pyriformis muscle, it is distributed solely to the gluteus maximus muscle. It gives off in rare cases the nerve to the short head of the biceps muscle.

(*b*) **Two Anterior (ventral) Branches.**—(1) The nerve to the **obturator internus** muscle arises from the front of the anterior trunks of the fifth lumbar and first two sacral nerves, or from the first three sacral nerves. Leaving the pelvis through the great sacro-sciatic foramen, it lies on the spine of the ischium in company with the internal pudic vessels and nerve, and passing through the small sacro-sciatic foramen it supplies the obturator internus muscle on its deep surface. It gives off the nerve to the **superior gemellus** muscle.

(2) The nerve to the **quadratus femoris** muscle arises from the front of the anterior trunks of the fourth and fifth lumbar and first sacral nerves. It passes through the buttock, concealed by the great sciatic nerve and by the obturator internus and gemelli muscles. It ends on the deep surface of the quadratus femoris, and supplies the nerve to the **inferior gemellus.**

The reason of the quadratus femoris, which appears as a *lower* muscle than the obturator internus, being supplied by nerves *higher* in the series, is to be found in the rotation of the limb, which has altered the relative position of the two muscles.

The Distribution of the Great Sciatic Nerve

The great sciatic nerve at the lower border of the pyriformis muscle consists of three elements bound together in a delicate fibrous sheath—from without inwards,—**peroneal, tibial,** and **nerve to the hamstring** muscles (Fig. 32).

Having predicated that the peroneal and tibial (external and internal popliteal) nerves are entirely distinct in origin, if we turn to their distribution we find a similar distinction. The peroneal nerve has a dorsal distribution—to the muscles and skin of the dorsal aspect of the leg and foot; while the tibial nerve has a ventral distribution—to the back of the leg and the sole of the foot (originally ventral surfaces). The nerve to the hamstrings is not only ventral in origin, but also in distribution.

The **nerve to the hamstring muscles** may or may not be regarded as a collateral branch of the tibial nerve. It supplies branches to the following muscles:

Adductor magnus . .	(L. 4, 5)
Semimembranosus . .	L 4, 5, S. 1.
Semitendinosus . . .	(L. 5. S. 1, 2)
Biceps (long head) . .	(S. 1. 2, 3)

It is to be noted that the inner (pre-axial or cephalic) muscles are supplied by nerves higher in position than the outer (post-axial or caudal) muscles. All these muscles are ventral in position.

The adductor magnus muscle has a double nerve supply, due to its formation from two masses of muscular tissue. Both are ventral—one associated with the adductor group of muscles, supplied by the obturator nerve, the other associated with the hamstring group, supplied by the nerve to the hamstrings. It is noteworthy that the innervation is numerically continuous (L. 3, 4, 5. S. 1).

The Peroneal (External Popliteal) Nerve

(1) **In the thigh,** while incorporated in the great sciatic nerve, the peroneal nerve gives off only one branch as a rule—the nerve to the short head of the biceps. With this is associated a fine filament for the outer side of the knee joint (Fig. 29).

This nerve, as already stated, in rare cases is a branch of the inferior gluteal nerve, the nerve to the gluteus maximus muscle.

The short head of the biceps is a separated portion of the gluteus maximus. It is a dorsal muscle, and in Ruminants forms a continuous portion of the gluteus maximus. In man it has become almost completely detached from the gluteus maximus and has become united with the long head of the biceps—a ventral muscle.

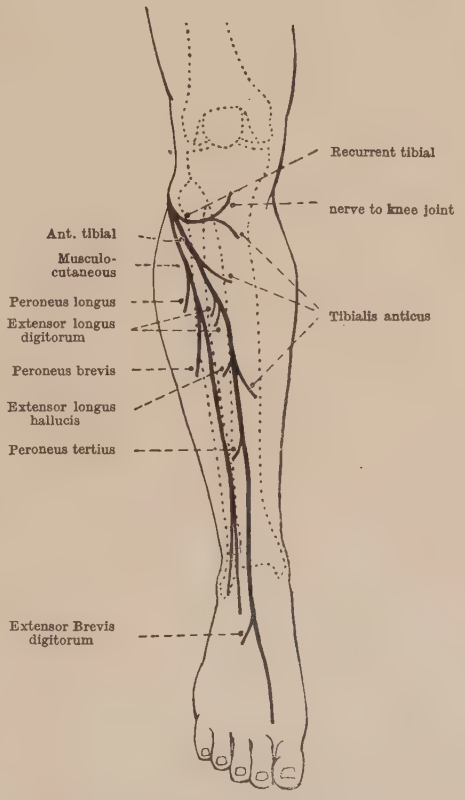


Fig. 31.—Front of Leg and Dorsum of Foot: Peroneal Nerve.

(2) In the **popliteal space,** after separating from the great sciatic trunk, the peroneal nerve follows the course of the biceps tendon, and becomes superficial at the outer side of the space. It courses downwards and outwards

parallel to that tendon to a point just below the head of the fibula, where it can be felt as a "funny bone." It is immediately beneath the fascia lata, and there divides into its three terminal branches—**anterior tibial recurrent, anterior tibial,** and **musculo-cutaneous.**

Collateral Branches (Fig. 26).—The peroneal nerve gives off in this part of its course two sets of collateral branches :—

(1) **Communicans fibularis,** which passes down the back of the leg under the deep fascia to unite with the corresponding branch (**communicans tibialis**) from the tibial nerve to form the short or **external saphenous nerve.**

(2) **Sural Branches.**—Several branches arise from the peroneal nerve before its final subdivision to supply the skin over the back and outer side of the calf of the leg (Fig. 29).

The **Terminal Branches** separate from the peroneal nerve below the head of the fibula, and just before their disappearance beneath the origin of the peroneus longus muscle (Fig. 31).

(1) **Anterior Tibial Recurrent Nerve.**—This nerve is the highest of the three at their origin. It supplies the knee joint and the upper fibres of the tibialis anticus.

(2) **Anterior Tibial Nerve.**—This nerve is intermediate in position at its origin. Clinging to the fibula it passes downwards and forwards beneath the origins of the peroneus longus and extensor communis digitorum muscles.

On the front of the leg it is deeply placed, lying on the interosseus membrane, between the tibialis anticus and extensor proprius hallucis muscles. At the ankle it passes in front of the lower end of the tibia and is crossed by the tendon of the extensor longus hallucis.

On the dorsum of the foot it divides into its terminal branches, external and **internal.** It is accompanied in its course by the anterior tibial and dorsalis pedis arteries.

Collateral Branches (Fig. 31).—The anterior tibial nerve supplies the extensor group of muscles on the front of the leg :

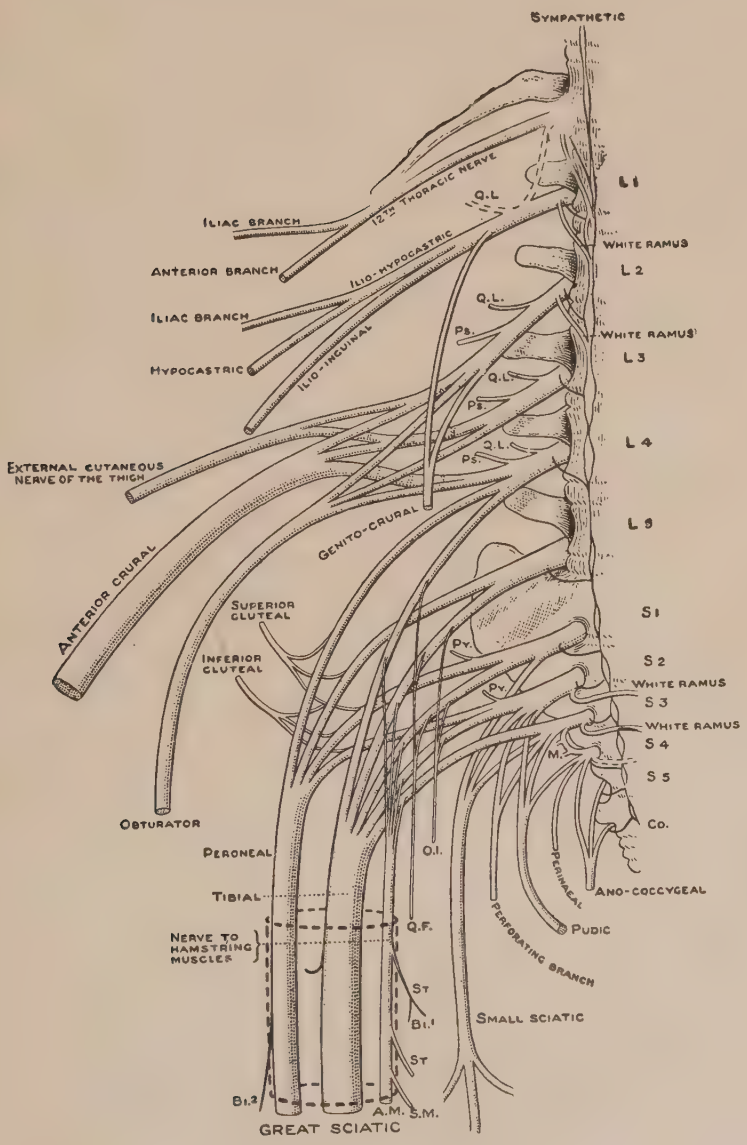


FIG. 32.—Lumbo-sacral Plexus.

Tibialis anticus . . (L. 4, 5. S. 1.)
Extensor longus hallucis (L. 4, 5. S. 1.)
Extensor longus digitorum (L. 4, 5. S. 1.
Peroneus tertius . . (L. 4, 5. S. 1.)

Terminal Branches.—(1) **External.** On this branch is a distinct ganglionic enlargement. It supplies the **extensor brevis digitorum** muscle and the articulations of the tarsus.

(2) **Internal.**—This branch passes to the interval between the first and second toes, and supplies a small area of the skin of the dorsum of the foot and the adjacent sides of these toes (Fig. 26).

It is noteworthy that throughout the primates, as well as in many other mammals, the anterior tibial nerve has this distribution to the skin of the foot.

(3) **Musculo-cutaneous Nerve.**—This nerve passes obliquely downwards and forwards, lying at first between the origin of the peroneus longus and the fibula. It then occupies a fibrous sheath in the septum between the extensor and peronei muscles, and pierces the deep fascia below the middle of the leg. It divides into two terminal branches, internal and external, for the supply of the skin of the front of the leg and the dorsum of the foot and toes.

Collateral Branches.—Two **muscular branches** are supplied for the **peronei longus** and **brevis**, while the nerve is deeply placed. The nerve for the peroneus longus arises while the nerve lies beneath that muscle. That for the peroneus brevis arises in the upper third of the leg (Fig. 31).

Terminal Branches.—These are both cutaneous nerves.

The **internal** branch supplies the skin of the front of the leg in the lower half, and the inner part of the dorsum of the foot. It ends in two branches, one for the supply of the inner side of the foot and great toe, the other for the skin between the second and third toes. The internal branch communicates with the internal saphenous nerve and with the cutaneous branch of the anterior tibial nerve (Fig. 26).

The **external** branch supplies the skin of the front of the leg and the outer side of the dorsum of the foot. It ends by dividing into two branches for the supply of the skin between the third and fourth and fourth and fifth toes. It communicates on the outer side of the foot with the external saphenous nerve.

Tibial (Internal Popliteal) Nerve

This nerve is the tibial or internal popliteal portion of the great sciatic trunk. It is ventral in origin and in distribution. It passes through the thigh, popliteal space, and leg, and finally divides at the ankle into the external and internal plantar nerves, midway between the internal malleolus and the os calcis. It corresponds to the median and ulnar nerves in the upper limb. It is a larger nerve than the peroneal (Fig. 29).

Course.—It extends down the back of the thigh, incorporated for a variable distance with the peroneal nerve, under cover of the hamstring muscles. It passes in a vertical direction through the popliteal space, superficial to the vessels.

In the back of the leg the nerve, now known as the *Posterior Tibial Nerve*, is deeply placed beneath the gastrocnemius, soleus, and plantaris, and accompanies the posterior tibial vessels to the ankle. It lies on the inner side of the posterior tibial artery at its beginning, but is external to the artery at its termination.

Collateral Branches (Fig. 29).—(1) In the thigh.

(*a*) A small branch is given off in the upper part of the thigh to the **hip joint.**

(*b*) Lower down branches are given off to the inner side and back of the **knee joint.**

(2) In the popliteal space.

(*a*) **Communicans Tibialis.**—This branch arises in the popliteal space and passes downwards in the sulcus between the heads of the gastrocnemius muscle. Piercing

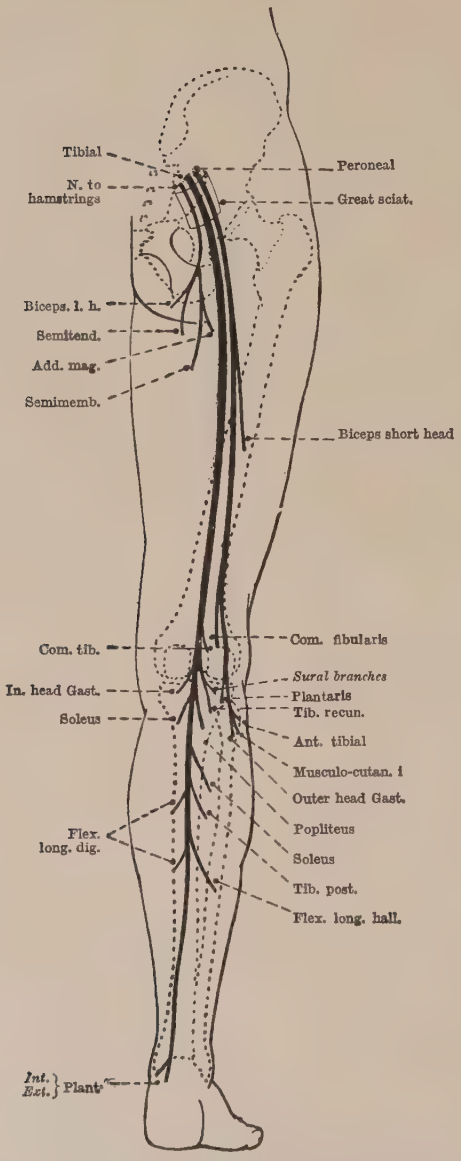


FIG. 33.—Distribution of Great Sciatic and Tibial Nerves.

the deep fascia about the middle of the calf it unites with the **communicans fibularis nerve** from the peroneal nerve to form the **external**, or short, **saphenous nerve.**

The **external saphenous nerve** supplies the lower third of the leg on the outer side, and the outer side of the foot and little toe. In a minority of cases it spreads on to the dorsum of the foot, and may supply the skin of one and a half toes on the outer side of the foot (Fig. 26).

In many cases the two communicating nerves fail to unite. In such cases one is carried to the foot, the other innervating the outer side of the leg. They are typical "border line" nerves, supplying the skin along the caudal or post-axial border of the limb.

(*b*) **Muscular Branches.**—The tibial nerve gives off branches in the popliteal space to the following muscles :

Gastrocnemius .	(each head) (S. 1, 2.)
Plantaris . .	(L. 4, 5, S. 1.)
Soleus . .	(S. 1, 2.)

Posterior Tibial Nerve

At the lower border of the popliteus muscle the tibial or internal popliteal becomes the posterior tibial nerve. It lies at first on the inner side of the posterior tibial artery, but crosses over it in its course down the leg, so that at the ankle it is external to it. The nerve and vessels occupy a sheath of deep fascia formed in the septum between the superficial and deep muscles (Fig. 33).

Collateral Branches.—In its course the following branches arise :

(1) **Muscular branches** to :

Soleus	(L. 5. S. 1, 2.)
Flexor longus hallucis .	(L. 5. S 1, 2.)
Tibialis posticus . .	(L. 5. S. 1.)
Flexor longus digitorum .	(L. 5. S. 1.)

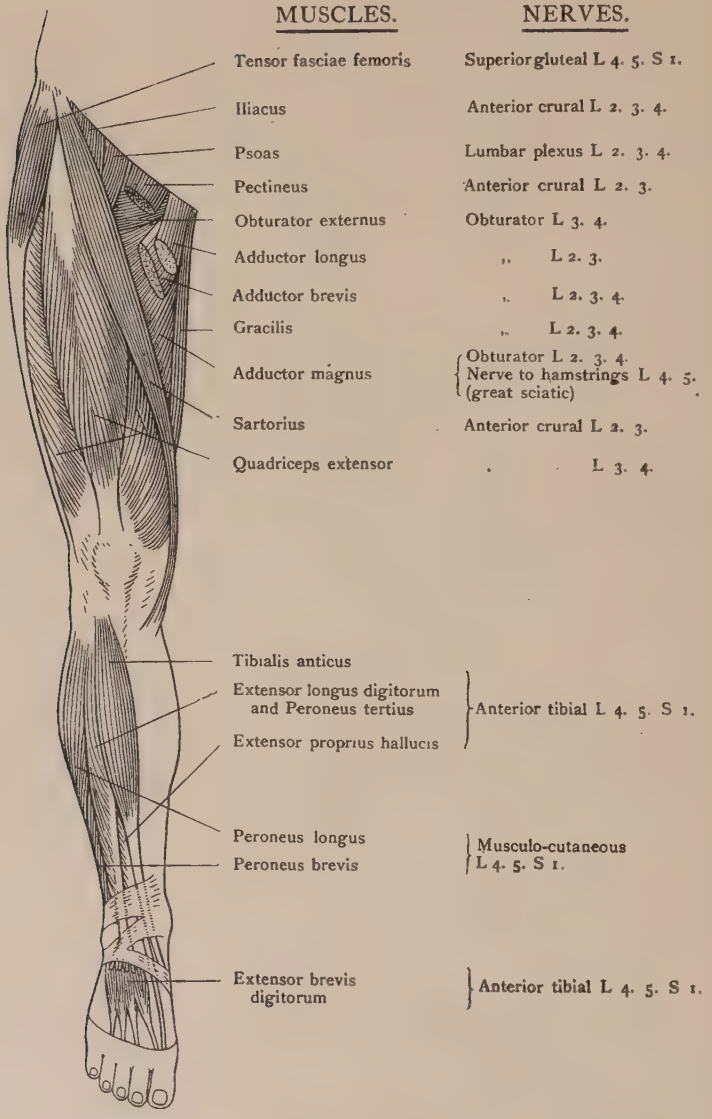
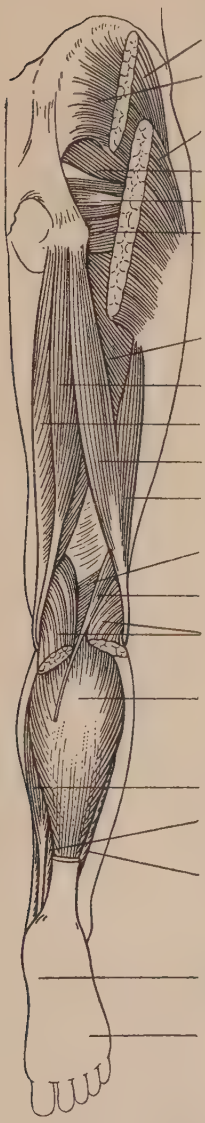


FIG. 34.—Innervation of the Muscles of the Lower Limb. Front of the Limb.



MUSCLES.	NERVES.
Gluteus medius Gluteus minimus	Superior gluteal L 4. 5. S 1.
Gluteus maximus	Inferior gluteal L 5. S 1. 2.
Pyriformis	S 1. 2.
Obturator internus and Gemelli	S 1. 2. 3.
Quadratus femoris	L 4. 5. S 1.
Adductor magnus	Obturator L 2. 3. 4. Nerve to hamstring (great sciatic), L 4 5.
Semitendinosus	,, ,, L 5. S 1. 2.
Semimembranosus	,, ,, L 4. 5. S 1.
Biceps (long head)	,, ,, S 1. 2. 3.
Biceps (short head)	Peroneal (external popliteal, great sciatic), L 5. S 1. 2.
Popliteus	Tibial (internal popliteal) L 4. 5. S 1.
Plantaris	,, L 4. 5. S 1.
Gastrocnemius	,, S 1. 2.
Soleus	Tibial S 1. 2. Posterior tibial L 5. S 1. 2
Flexor longus digitorum	,, ,, L 5. S 1.
Tibialis posticus	,, ,, L 5. S 1.
Flexor longus hallucis	,, ,, L 5. S 1. 2.
Muscles supplied by internal plantar nerve and by external plantar nerve	L 4. 5. S 1. S 1. 2.

FIG. 35.—Innervation of the Muscles of the Lower Limb. Back of the Limb.

(2) **Cutaneous Branch.**—The **Calcanean Nerve** (S. 1, 2) arises in the lower third of the leg and pierces the internal annular ligament close to the tuberosity of the os calcis. It supplies the skin of the heel and the back part of the sole of the foot (Fig. 26).

At the ankle, midway between the internal malleolus and the os calcis, the posterior tibial nerve divides into its terminal branches—**internal** and **external plantar nerves.** These correspond in general in their distribution in the sole of the foot to the median and ulnar nerves in the hand.

The **Internal Plantar Nerve** (L. 4, 5. S. 1) is distributed to the skin of three and a half toes on the inner side of the foot, and sends branches to the dorsum of the terminal phalanges of the corresponding toes.

Muscular branches are supplied to the following muscles:

Flexor brevis digitorum,
Adductor hallucis,
Flexor brevis hallucis,
First lumbrical muscle.

The **External Plantar Nerve** (S. 1, 2) crosses the sole of the foot obliquely between the first and second layer of muscles. It supplies cutaneous branches to one and a half toes on the outer side of the foot, and is distributed by its deep branch to the muscles of the foot, other than those supplied by the internal plantar nerve.

The Pudendal Plexus

As already stated, the pudendal plexus is formed for the most part by the anterior primary divisions of the spinal nerves behind (caudal to) the lumbo-sacral plexus. The nerve associated with both (*n. bigeminus*) is usually the third sacral nerve (Fig. 36).

In man the plexus is formed by higher nerves as well, so that it overlaps with the sacral portion of the plexus.

The nerves forming it are the second, third, fourth, and fifth sacral, and the coccygeal nerve. Occasionally the first sacral nerve is implicated as well. It gives rise to a series of nerves distributed for the most part to the perineum and caudal region. One of its chief trunks, the small sciatic nerve, is also distributed to the skin of the lower limb.

The following nerves arise from this plexus:

Small sciatic . .	(S. (1) 2, 3.)
Perforating cutaneous nerve . . .	(S. 2, 3).
Internal pudic . .	(S. 2, 3, 4.)
Perineal branch of the fourth sacral.	
Muscular branches to levator ani . .	(S. 3, 4.)
Visceral or splanchnic branches . . .	(S. 2, 3, or 3, 4.)
Sacro-coccygeal . .	(S. 4, 5. Co.)

The **Small Sciatic Nerve** arises from the anterior primary divisions of the second and third sacral nerves near their exit from the sacrum. It is occasionally reinforced by a filament from the first sacral nerve. The nerve passes into the buttock below the pyriformis muscle in company with the inferior gluteal nerve and sciatic artery. Lying on the great sciatic nerve it proceeds to the lower border of the gluteus maximus, where it separates into its terminal branches. It is a purely cutaneous nerve, and supplies three sets of branches:

(1) **Gluteal.**—These nerves sweep round the border of the gluteus maximus, and supply a considerable area of the skin of the buttock in its lower part (Fig. 26).

(2) **Perineal.**—There are usually several perineal branches which have a wide distribution to the skin of the inner side of the thigh in its upper third, the perineum, scrotum, and penis. One branch, the **long pudendal,** becomes cutaneous

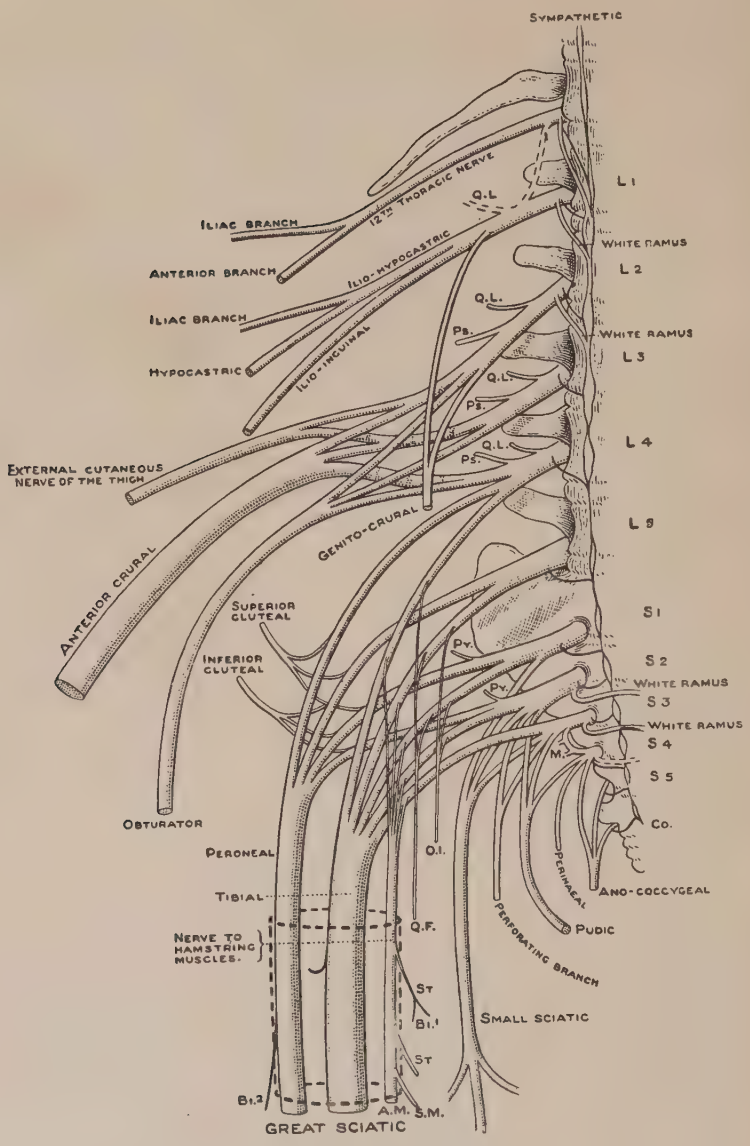


FIG. 36.—Lumbo-sacral Plexus.

in the anterior part of the perineum, passing between the deep fascia and the pubic arch. It supplies the skin over the anterior part of the perineum, the base of the scrotum, and root of the penis. It communicates by fine filaments with the superficial perineal branches of the internal pudic nerve.

(3) **Femoral.**—The remaining part of the small sciatic nerve passes down the back of the thigh, beneath the fascia lata. It usually divides into two trunks, external and internal, from which twigs arise at irregular intervals to supply the skin of the back of the thigh and popliteal space. The nerve is usually traceable down to the middle of the calf of the leg.

The small sciatic nerve is interesting for two reasons. It is a border-line nerve, having its distribution along the caudal border of the limb, as well as to the trunk, beyond the attachment of the limb (perineum). It is, as it were, drawn down the limb in the process of extension of the lower extremity. It is also comparable to a typical thoracic nerve, and may be well compared with the second thoracic in the features of its distribution. The perineal branches represent the anterior terminal branch of a typical thoracic nerve. The gluteal branches are obviously homologous with the posterior part of a lateral branch; while the femoral branches possibly contain elements corresponding to the anterior part of the lateral branch of the nerve.

The **Perforating Cutaneous Nerve** arises from the second and third sacral nerves. It is closely associated at its origin with the roots of the small sciatic nerve. After piercing the great sacro-sciatic ligament it winds round the border of the gluteus maximus, and supplies an area of skin over the lower part of the buttock between the areas supplied by the gluteal branches of the small sciatic and the perineal branch of the fourth sacral nerve.

This nerve is not always present, or it may arise from the small sciatic or internal pudic nerve.

The **Internal Pudic Nerve** arises from the anterior surfaces of the second, third, and fourth sacral nerves. Entering the buttock below the pyriformis through the great sacro-sciatic foramen, it crosses the ischial spine, lying on the inner side of the internal pudic artery—to re-enter the pelvis through the small sacro-sciatic foramen. It courses forwards in the outer wall of the ischio-rectal fossa with the pudic artery. They are contained in a special sheath of the obturator layer of the pelvic fascia covering the obturator internus muscle (Alcock's canal). The nerve passes beneath the triangular ligament of the urethra, and finally divides beneath that ligament into its terminal branches—the **nerve to the corpus cavernosum** of the penis (or clitoris) and the **nerve to the dorsum** of the penis (or clitoris). These nerves pierce the triangular ligament in company with small arteries to reach their destination.

The internal pudic nerve is purely a trunk nerve, being distributed solely to the perineum (Fig. 37).

Collateral Branches. — (1) **Inferior Hæmorrhoidal Nerve** (S. 3, 4).—This nerve arises from the pudic nerve while it occupies the outer wall of the ischio-rectal fossa. Accompanied by the artery of the same name it crosses the ischio-rectal fossa, dividing in its course into a sheaf of branches which are distributed to the external sphincter ani muscle and the skin around the anus. It communicates with the superficial perineal and the long pudendal nerves.

(2) **Superficial Perineal Nerves** (S. 2, 3).—Posterior or external, anterior or internal.—The posterior nerve has the longer course in the ischio-rectal fossa. They both arise from the parent trunk while it is still in Alcock's canal; leaving the ischio-rectal fossa they pass over or through the transversus perinei muscle, to reach the anterior part of the perineum. They are distributed to the skin of the perineum, the inner side of the thigh, the scrotum, and penis. They communicate with the inferior hæmorrhoidal and long pudendal nerves.

In the female they are distributed mainly to the labia majora.

(3) **Deep Perineal Nerve** (S. 2, 3).—This is mainly muscular in its distribution. Arising from the pudic nerve in the ischio-rectal fossa, just behind the transversus perinei muscle, it proceeds inwards and forwards and

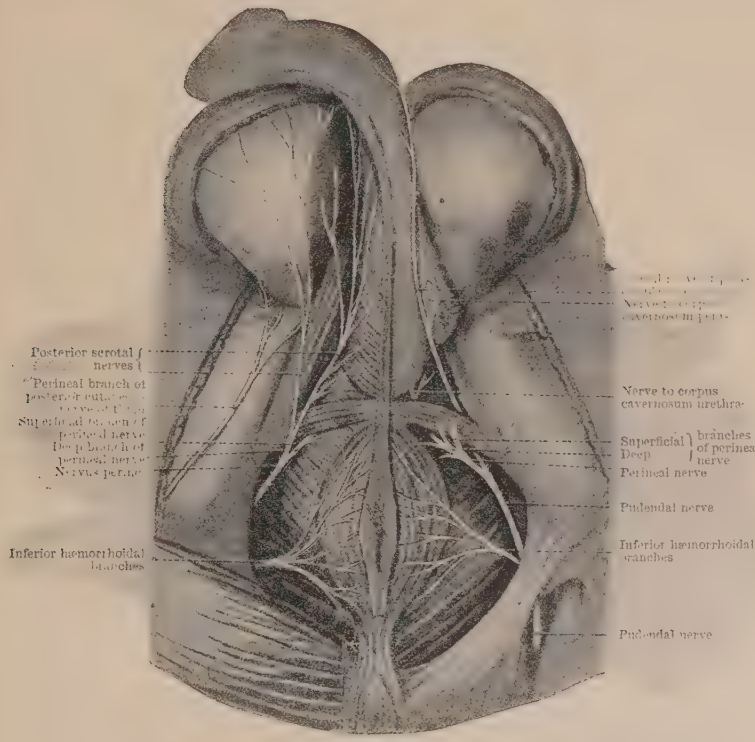


Fig. 37.—Distribution of the Internal Pudic Nerve.

divides into branches for the supply of the following muscles: external sphincter ani, levator ani, transversus perinei, bulbo-cavernosus, erector penis, and compressor urethræ. One branch, the **nerve to the bulb**, pierces the bulb of the penis, and supplies the corpus spongiosum and the mucous membrane of the penile portion of the urethra.

The **dorsal nerve** of the penis (or clitoris) may be regarded as the terminal branch of the internal pudic nerve. Passing with the dorsal artery between the layers of the suspensory ligament, it communicates with the cavernous plexus of the sympathetic, and is distributed to the skin of the dorsum and sides of the penis, reaching forward as far as the glans. Some filaments enter and supply the corpus cavernosum.

The **Perineal Branch of the Fourth Sacral Nerve** arises from the front of the parent nerve. It pierces the ischio-coccygeus muscle and appears in the perineum in the angle between the external sphincter and gluteus maximus muscles. It supplies the external sphincter ani muscle and the skin of the perineum behind the anus.

The external sphincter ani muscle is thus innervated by three nerves—deep perineal and inferior hæmorrhoidal from the internal pudic, and by the perineal branch of the fourth sacral nerve.

Branches to the Levator ani Muscle.—These nerves arise separately from the front of the third and fourth sacral nerves. They supply the muscle on its visceral surface. The levator ani is also supplied by the deep perineal branch of the internal pudic nerve.

Visceral Nerves (S. 2, 3, or 3, 4).—These are pelvic splanchnic or visceral nerves corresponding to the white Rami communicantes of the thoracic and lumbar regions. They differ, however, in an essential feature. They pass *over* the gangliated cord of the sympathetic without being connected with it, and enter directly the pelvic sympathetic plexus. They pierce the pelvic fascia alongside the rectum, and become connected at once with the pelvic sympathetic plexus.

Sacro-coccygeal Nerve (S. 4, 5. Co.).—This represents the **inferior caudal nerve** of tailed animals. It is formed by a part of the fourth sacral, the fifth sacral, and the coccygeal nerves. A rudimentary trunk is formed by the successive union of these small nerves, which is distributed to the skin beside the coccyx.

While to some extent intermingled at their origin with the lumbo-sacral plexus, the nerves of the pudendal plexus are essentially distributed to the perineum and caudal regions—behind the proper attachment of the limb. The perineum in its innervation represents the junction of the distribution of the anterior terminal branches of the anterior primary divisions of the nerves which supply the trunk in front of and behind the limb.

The first lumbar nerve, represented by the ilio-inguinal, sweeps down in front of the limb (along its cephalic border) and reaches the root of the penis and the base of the scrotum. The other nerves supplying the perineum—small sciatic, perforating cutaneous, internal pudic, perineal branch of the fourth sacral, and the sacro-coccygeal nerves—reach the perineum from behind the attachment of the limb, along its caudal border. These nerves are derived from the last four sacral and coccygeal nerves.

In their distribution to the genital organs and perineum they can be shown to have a distinctly numerical order, the anterior parts (penis and scrotum) being supplied by the higher nerves (S. 2, 3), the posterior parts—through the inferior hæmorrhoidal nerve (S. 3, 4)—behind which appear the perineal branch of the fourth sacral, and last of all the sacro-coccygeal nerve (S. 4, 5. Co.).

In the case of the upper limb and lower limb alike the limb is as it were thrust out from the trunk, carrying with it the whole of the anterior primary division of each spinal nerve supplying it, except at its borders, where trunk nerves are carried out in part to supply the skin along the cephalic, and more particularly along the caudal borders (intercosto-humeral and small sciatic nerves).

CHAPTER III

THE SYMPATHETIC SYSTEM

The sympathetic system is subordinate to the spinal nervous system. It is primarily dependent on that system for its initial energy. The cerebro-spinal fibres joining it are the white Rami communicantes, which, taking origin from both dorsal ganglionic, and ventral roots of certain spinal nerves, contain therefore both afferent and efferent fibres.

The gangliated cord itself, consisting of a column of pseudo-segmental ganglia and connecting commissures, gives rise to a series of nerves, for the most part non-medullated, which are distributed both centrally and peripherally. The central branches constitute the grey Rami communicantes, which pass from the gangliated cord to the anterior primary divisions of the spinal nerves. The peripheral branches pass into the splanchnic area, and are distributed to viscera and vessels. They consist of non-medullated fibres—the branches from the ganglia—with which are mingled numbers of medullated fibres, which are proceeding from the viscera in the splanchnic area through the gangliated cord and the white Rami communicantes to the dorsal ganglionic roots of certain spinal nerves.

The sympathetic system receives fibres from the cerebro-spinal nervous system, which become associated with the cells of its ganglia—afferent and efferent fibres, derived from the dorsal and ventral roots of certain spinal nerves. In association with the ventral root, *efferent* fibres, the cells of the ganglia give rise to a series of nerves, motor

in function, which are central and peripheral in their distribution. The central fibres pass as **grey Rami communicantes** to the roots and trunks of the spinal nerves, and serve as pilo-motor and vaso-motor fibres. The peripheral fibres form nerves which pass to the vessels in the splanchnic area as vaso-motor fibres. The *afferent* fibres, which join ultimately the dorsal roots of certain spinal nerves, come from the viscera. They are conveyed in the splanchnic (visceral) branches of the sympathetic, back to the gangliated cord, and through it to the **white Rami communicantes,** and thereby to the dorsal roots and ganglia of certain spinal nerves (Fig. 38).

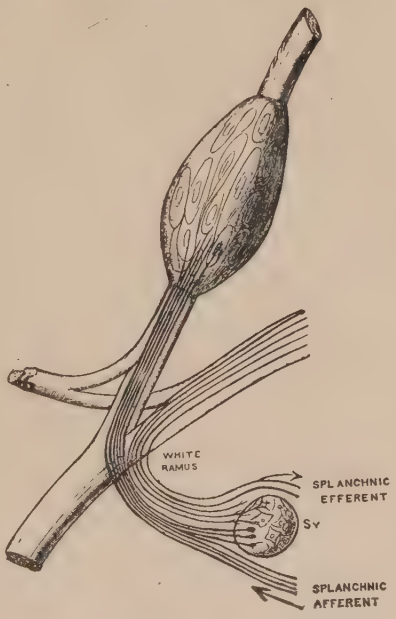


FIG. 38.—Connection of Spinal Nerves and Sympathetic System.

DEVELOPMENT AND MORPHOLOGY

In a young embryo, before the roots of the spinal nerves have united, there appears on either side of the aorta a cylindrical column of cells, which is the precursor of the sympathetic gangliated cord. It does not extend at first into the cervical region, nor beyond the bifurcation of the aorta.

After the formation of the trunk of the spinal nerve, the posterior primary divisions having separated from the anterior primary divisions, the latter nerves, in certain regions, may be seen to subdivide, at the junction of the body wall and splanchnic area, into unequal parts (Fig. 43)

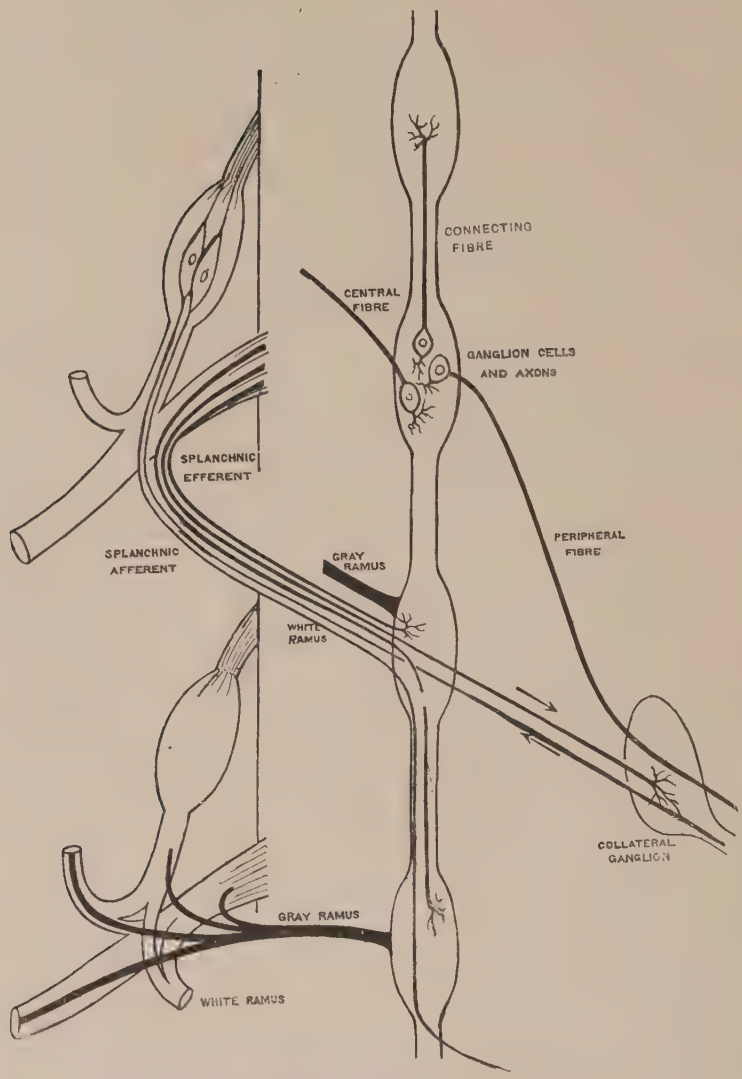


FIG. 39.—Sympathetic System, and Connections.

—a large **somatic** part, the distribution of which has already been described, and a small **splanchnic** or **visceral** branch, which is the white Ramus communicans. This is directed

inwards into the splanchnic area, where it is connected with the column of cells already mentioned.

Here the nerve separates into two series of fibres, of which one joins the cellular column, while the other passes over it, either directly into the splanchnic area, or after a longer or shorter course in association with the cellular column (Figs. 38, 39). The connection of these visceral or

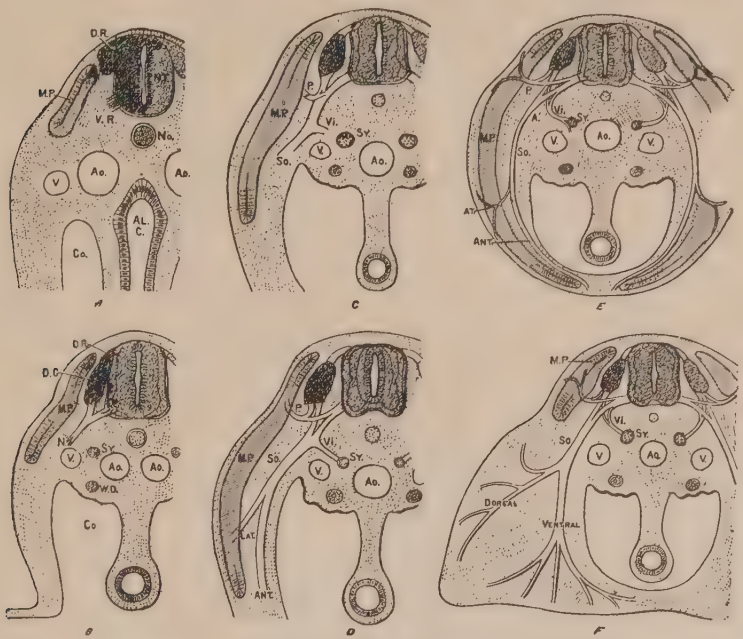


FIG. 40.—Development of a Sympathetic Nerve.

splanchnic branches of the spinal nerves with the cellular column causes the persistence of the cells as ganglion cells, which thus become collected into more or less segmental ganglia, while the parts of the column between these collections produce the commissure.

These splanchnic or visceral branches, or white Rami communicantes, only occur in relation to certain spinal nerves. They are found in association with the thoracic and lumbar nerves, and with the second and third or third

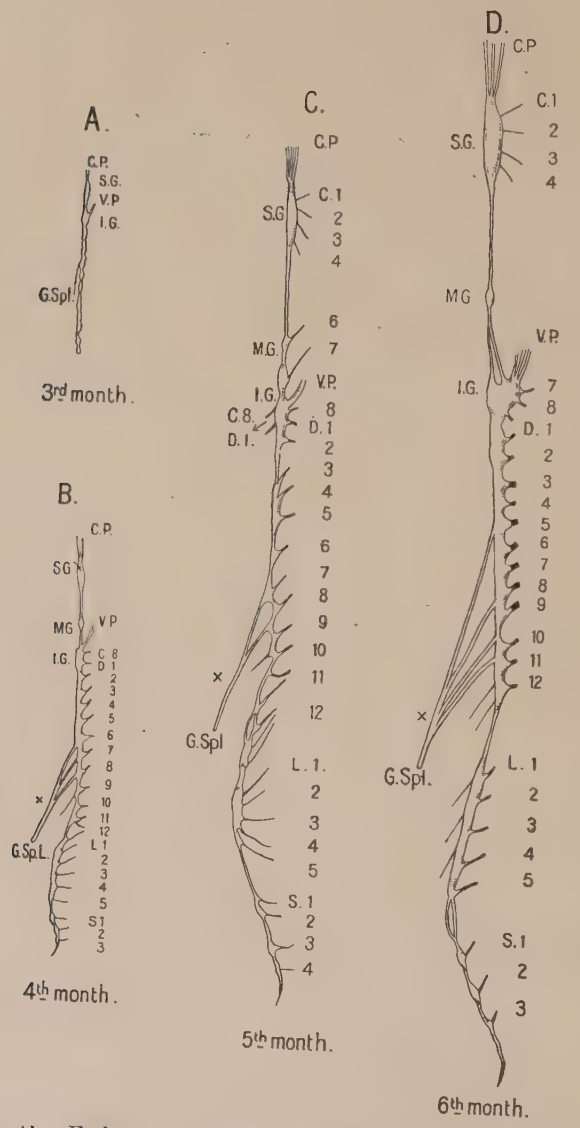


FIG. 41.—Embryonic Sympathetic Cord—Longitudinal View.

and fourth sacral nerves. These latter are the *pelvic splanchnic nerves* already referred to. They differ from the thoracico-lumbar stream, in that they do not join the gangliated cord, but pass directly into relation with the pelvic plexus of the sympathetic.

There are no white Rami communicantes in the neck, but there is an outflow of a similar kind in relation to the vagus and spinal accessory nerves.

The accessory part of the spinal accessory nerve gives off a slender branch to the upper ganglion of the vagus. The rest of it is connected with the lower ganglion. Some of the fibres join the ganglion at once and are connected with its cells, from which new fibres emerge, and passing down as non-medullated fibres, incorporated with the trunk of the vagus, become cardio-inhibitory in function. Some of the fibres pass over the ganglion and merge with the vagus trunk as medullated fibres. These constitute the cardio-motor and viscero-motor fibres of the vagus, distributed to the heart muscle and the muscular tissue of the alimentary canal.

Further Growth of the Sympathetic Cord.—The gangliated cord grows both forwards towards the head and backwards towards the coccyx. Extending through the neck along the carotid vessels it ends in close association with the internal carotid artery, to which it supplies plexiform fibres—the carotid and cavernous plexuses. It gives rise to two, or sometimes three, ganglia—superior, middle (often absent), and inferior cervical ganglia.

Growing backwards the sympathetic cord extends into the pelvis, where, finally, in front of the coccyx it is united to the cord of the opposite side by the *ganglion impar* or coccygeal ganglion.

As already noted these secondary extensions of the cord have no connection, by means of white Rami communicantes, with the spinal nervous system, although they give off a series of grey Rami communicantes to the spinal nerves.

Suprarenal Capsule

In the loin, in the region of the Wolffian body and developing kidney, at an early stage a stream of cells grows out from the simple cellular column, which extends ventrally, and gives rise to the medullary portion of the suprarenal body. This stream of cells is rich in **chromaffin** cells, which are closely associated with the structure and function of the suprarenals. The cortex of the suprarenal body is formed from the mesoblast of the Wolffian ridge, the inner part of which is raised up and thickened to form a suprarenal ridge.

It becomes separated from the endothelium lining the abdominal cavity, and is incorporated with the cellular outgrowth from the sympathetic cord to form the suprarenal capsule.

Distribution of the Sympathetic System

The gangliated cord of the sympathetic extends from the base of the skull to the coccyx. Above, it is continued into the carotid and cavernous plexuses along the internal carotid artery. Below, it is united to the cord of the other side by the coccygeal ganglion or ganglion impar.

It is not strictly segmental. The ganglia are pseudo-segmental, and the apparent segmentation is best marked in the regions where the white Rami communicantes occur—thoracic and lumbar. Even here, however, the ganglia are usually fewer than the number of junctional nerves. There is a frequent coalescence or want of separation of ganglia; and in the loin and sacral region one finds in not a few cases examples of one elongated ganglion instead of five. In the cervical region there are at most three, and often only two ganglia.

The **White Rami Communicantes** are found in two streams—thoracico-lumbar and sacral. The thoracic and

lumbar white Rami are associated with all the thoracic and lumbar nerves, although the first thoracic nerve may give off no white Ramus, and those associated with the last three lumbar nerves are very small. The white Rami in the upper half of the thorax (T. 1–6), after entering into relation with the sympathetic gangliated cord, form a stream of fibres which are directed for the most part upwards into relation with the cervical portion of the cord, while the lower half of the thoracic white Rami stream downwards, and are for the most part distributed in the abdomen and pelvis.

The **Grey Rami Communicantes** are very irregular in their arrangement. The anterior primary division of each and every spinal nerve receives a grey Ramus communicans, which is distributed to the roots and trunk of the nerve. But the ramus need not necessarily arise from a sympathetic ganglion. They may arise from the commissural cord between the ganglia; a single Ramus may bifurcate to supply two adjacent spinal nerves; or two grey Rami may proceed to one spinal nerve.

Collateral Branches.—While the grey Rami are to be regarded as collateral branches, there are numerous others arising from all regions of the gangliated cord, which are distributed peripherally to the vessels and viscera of the splanchnic area.

For convenience of description the gangliated cord of the sympathetic is divided regionally into cervical, thoracic, lumbar, and pelvic or sacral parts.

A. Distribution of the Sympathetic in the Neck (Fig. 42).—The cervical sympathetic cord extends from the base of the skull to the neck of the first rib, where it becomes continuous with the thoracic portion of the cord. It consists of a long slender commissure, with a ganglion at each end, and occasionally a third minute ganglion in an intermediate position.

The cord lies in front of the prævertebral muscles, behind the internal and common carotid arteries. The superior cervical ganglion gives off two bundles of plexiform nerve

fibres, which surround the internal carotid artery just before it enters the carotid canal in the temporal bone, and form the *carotid* and *cavernous plexuses*. At its lower end the sympathetic cord passes behind the subclavian artery in the first part of its course, forming behind the vessel the

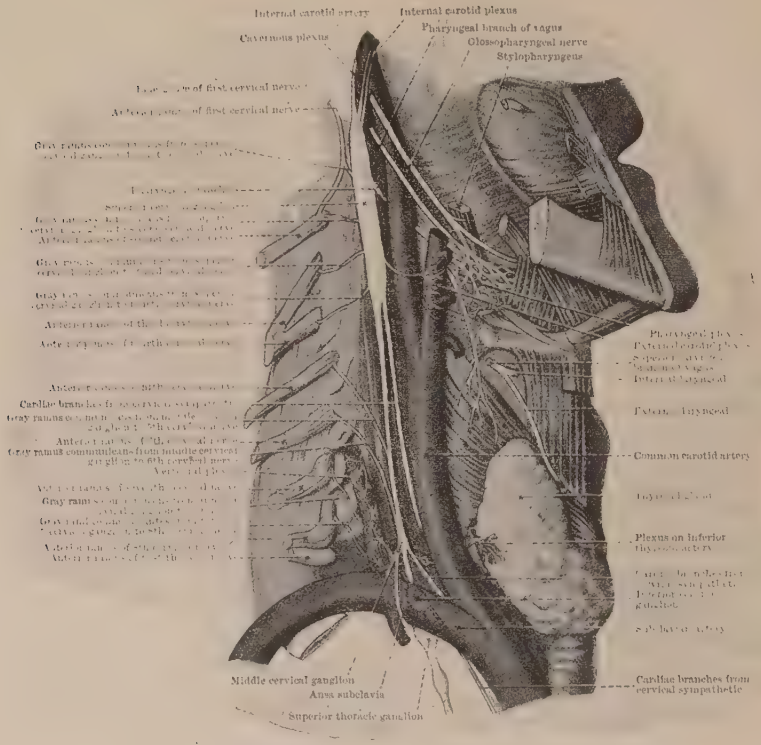


FIG. 42.—Distribution of the Sympathetic in the Neck.

inferior cervical ganglion (*g. stellatum*), which is partially fused with the first thoracic ganglion.

The cervical part of the sympathetic system receives no white Rami communicantes from the spinal nerves. Its cerebro-spinal connections come from the white Rami of the upper six thoracic nerves, which ascend in the sympathetic cord to reach the neck.

Grey Rami communicantes pass to all the spinal nerves from the cervical ganglia. The first four nerves receive branches from the superior cervical ganglion; the fifth and sixth nerves from the intermediate ganglion, or, when that is absent, from the commissural cord; and the seventh and eighth nerves, from the inferior ganglion.

In addition, each ganglion supplies peripheral branches, for the supply of viscera and vessels, or to communicate with other nerves.

Branches of the Superior Cervical Ganglion

(1) **Communicating branches** connect this ganglion with the glosso-pharyngeal, vagus, and hypoglossal nerves.

(2) **Vascular Branches.**—(*a*) **Carotid** and **cavernous plexuses,** as already stated, are associated with the internal carotid artery, and are distributed along that vessel within the cranium. They form communications with certain cranial nerves—the third, fourth, and sixth. Through the cavernous plexus a small filament passes to the ciliary ganglion; and through the great deep petrosal nerve, which joins the great superficial petrosal nerve from the facial to form the *vidian nerve*, a connection is effected with the spheno-palatine (Meckel's) ganglion.

(*b*) **Branches to the external carotid artery** pass downwards and join the external carotid artery near its origin. They communicate with the small **intercarotid ganglion,** placed in the angle of separation of the external and internal carotid arteries. A plexus is formed round the external carotid artery, which supplies subordinate plexuses along the branches of the artery. By these means sympathetic fibres reach the **otic ganglion** (through the plexus on the middle meningeal artery) and the **submaxillary ganglion** (through the plexus on the facial artery).

(3) **Visceral Branches.**—(*a*) A **pharyngeal branch** passes obliquely downwards and forwards behind the internal carotid artery to join the pharyngeal plexus, completed by

the glosso-pharyngeal nerve, and the pharyngeal branch of the vagus.

(*b*) The **superior cervical cardiac branch** is a slender nerve which passes down into the thorax to join the cardiac plexus. On the right side, this nerve passes behind the subclavian artery, and joins the deep part of the plexus. On the left side, the branch joins the superficial part of the plexus after passing in front of the aortic arch (Fig. 62).

Branches of the Intermediate Cervical Ganglion

This ganglion is placed behind the common carotid artery and in front of the inferior thyroid artery. It is not always present. When absent the branches associated with it spring from the commissural cord. Its peripheral branches are three.

(1) **Thyroid Branches.**—These form a plexus surrounding the inferior thyroid artery, and are distributed to the thyroid gland.

(2) The **middle cervical cardiac branch** descends into the thorax, and on each side joins the deep part of the cardiac plexus.

(3) **Ansa Subclavia.**—From the intermediate ganglion (or the commissure) a bundle of fibres passes down in front of the subclavian artery, and, looping round it, joins the inferior ganglion. This is the ansa subclavia or ansa Vieusenii. From it branches arise which supply the subclavian artery.

Branches of the Inferior Cervical Ganglion

(1) **Communicatng Branches.**—On the right side a communication is effected with the recurrent laryngeal branch of the vagus.

On both sides the inferior and intermediate ganglia are joined together by the *ansa subclavia.*

(2) **Vascular Branches.**—Considerable bundles join the vertebral artery to form the vertebral plexus (In birds

the gangliated cord in the neck accompanies the vertebral artery through the foramina transversaria.)

(3) The **inferior cervical cardiac branch** passes to join the deep part of the cardiac plexus.

Distribution of the Sympathetic System in the Thorax

The gangliated cord of the sympathetic in the cavity of the thorax is placed alongside the vertebral column on the necks of the ribs (Fig. 43). It is placed behind the costal pleura, upon the intercostal vessels. At the upper end the first thoracic ganglion is partially fused with the last cervical ganglion (*g. stellatum*). At the lower end a delicate commissural cord pierces or passes behind the diaphragm, to be continuous with the lumbar portion of the cord.

The ganglia present are not strictly segmental. They are often fused together, so that one long ganglion may represent as many as three (segmental) ganglia.

Central Connections.—White Rami Communicantes pass from the anterior primary divisions of all the thoracic spinal nerves to join the gangliated cord. Each white Ramus possesses fibres associated with both dorsal ganglionic and ventral roots of the spinal nerves.

Reaching the gangliated cord the efferent fibres from the ventral root become associated with the ganglia, while the afferent fibres, which are associated with the dorsal ganglionic root, pass over the ganglia, and after a variable course in the commissure pass to the periphery without any direct connection with the gangliated cord (Fig. 38).

The white Rami in the upper half of the thoracic region constitute a stream of fibres, which are directed upwards in the commissure into the neck, where they are distributed as branches of the cervical sympathetic. In the lower half of the thorax they are directed for the most part downwards, in the commissure, so as to become connected

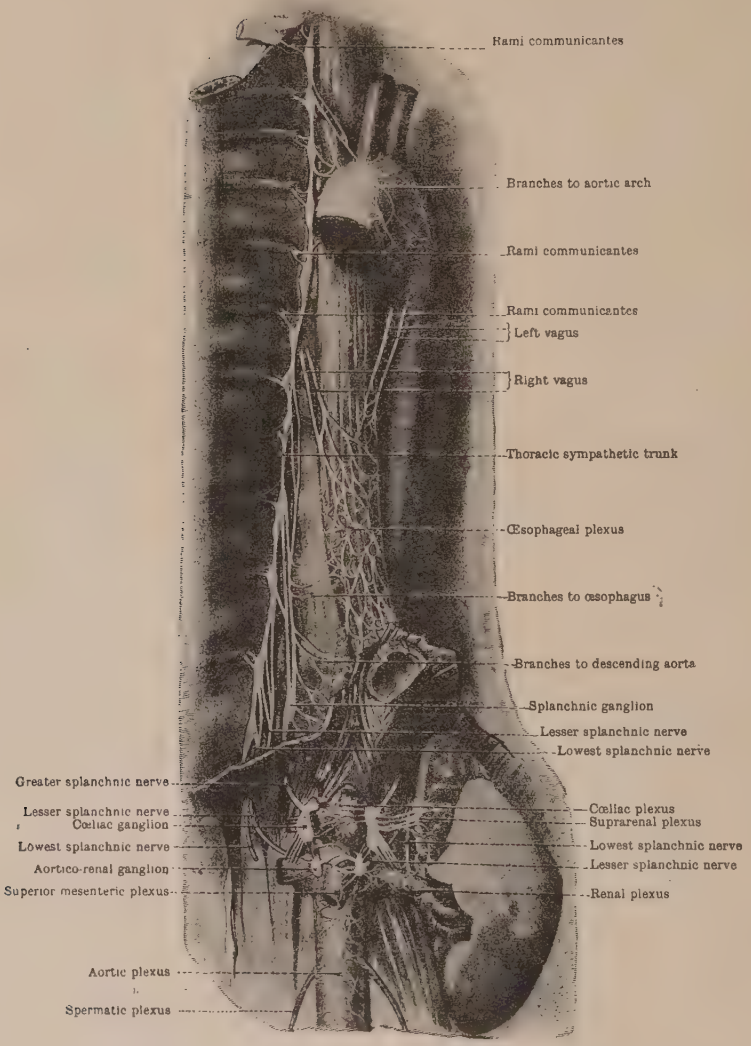


FIG. 43 —The Sympathetic Trunk in the Thorax.

with the solar and aortic plexuses, and join in the distribution of the sympathetic in the abdomen.

Grey Rami Communicantes, as already described, pass

from the ganglia and commissure in quite an irregular way to supply the roots and trunk of each thoracic nerve. Each nerve receives at least one grey Ramus, and sometimes two. The Ramus may bifurcate in its course so as to supply two spinal nerves. They carry pilo-motor and vaso-motor fibres to the spinal nerves.

Peripheral Branches.—As already stated there is a distinct difference in the distribution of the upper and the lower parts of the thoracic sympathetic cord. In the upper part the stream of cerebro-spinal fibres is mainly upwards into the neck. The branches distributed in the thorax are only a few delicate filaments distributed to the aorta and the posterior pulmonary plexus.

Branches to the aorta arise from the upper four or five ganglia; **branches for the posterior pulmonary plexus,** from the third and fourth ganglia.

The Splanchnic Nerves

In relation to the lower half of the gangliated cord in the thorax three nerves are given off, which proceed downwards through the diaphragm to the abdomen, where they are distributed through the solar and aortic plexus to the abdominal vessels and viscera.

They are the three splanchnic nerves—great, small, and least. They arise irregularly from the cord and commissure, and consist of intermingled white and grey nerve fibres, of which the white fibres are the afferent fibres of the white Rami, proceeding beyond the gangliated cord to form ganglionic connections in relation to the viscera. The grey Rami are vaso-motor fibres which are axons of the cells of the sympathetic ganglia.

The Great Splanchnic Nerve arises from the gangliated cord and commissure by a number of roots between the levels of about the sixth to the ninth spinal nerves. It is directed downwards and forwards in the posterior mediastinum, alongside the aorta and œsophagus. It pierces the

crus of the diaphragm, and in the abdomen joins the upper end of the **semilunar ganglion** of the solar plexus. Just before it pierces the diaphragm it presents a small ganglionic enlargement—the **splanchnic ganglion.**

In the thorax the nerve and ganglion supply fine branches to the **œsophagus** and **aorta.**

The **Lesser Splanchnic Nerve** arises from the gangliated cord below the previous nerve, at the level of the ninth and tenth thoracic nerves. Piercing the diaphragm, the nerve joins the **aortico-renal ganglion,** situated at the root of the superior mesenteric artery.

The **Least Splanchnic Nerve** arises below the previous nerve. It is a small trunk which, after passing through the diaphragm, joins the **renal plexus.**

Summarising the splanchnic nerves, they have origins from the lower six thoracic nerves through the white Rami communicantes. Except for the branches given off from the great splanchnic nerve to the aorta and œsophagus, they are distributed wholly to structures placed below the diaphragm.

Distribution of the Sympathetic in the Abdomen

The lumbar portion of the sympathetic cord lies on the bodies of the lumbar vertebræ (Fig. 44), lateral to the large vessels and internal to the origin of the psoas magnus muscle. It is connected above by a fine attenuated cord which passes through or behind the diaphragm with the thoracic sympathetic. Below, it passes behind the common iliac vessels into the pelvis, where it is continuous with the pelvic gangliated cord. As in the thorax, the ganglia are by no means segmental. They are more or less merged with one another, and occasionally there is a single elongated ganglion.

Central Connections.—White Rami Communicantes are stated to pass to the gangliated cord from each lumbar nerve.

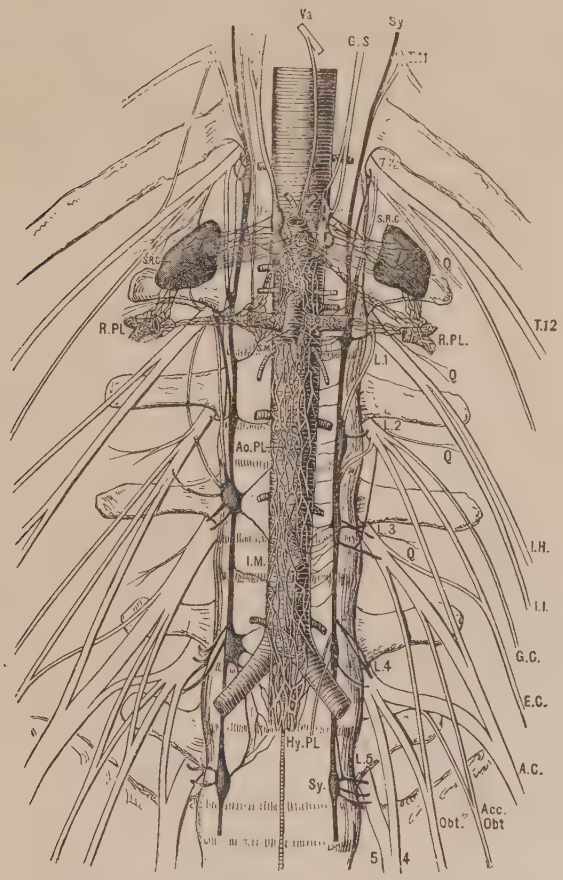


FIG. 44.—THE LUMBAR PORTION OF THE SYMPATHETIC GANGLIATED TRUNK AND LUMBAR PLEXUS.

(From a dissection.)

T.11, T.12, L.1, L.2, L.3, L.4, L.5, Anterior Rami of spinal nerves, with white and grey Rami communicantes.

Sy., Sympathetic trunk; Va., Vagus nerve; G.S., Greater splanchnic nerve, joining cœliac ganglion; S.R.C., Suprarenal gland and plexus; R.Pl., Renal plexus; Ao.Pl., Aortic plexus; S.M., Superior mesenteric plexus; I.M., Inferior mesenteric plexus; Hy.Pl., Hypogastric plexus; Q, Nerves to quadratus lumborum; I.H., Ilio-hypogastric nerve; I.I., Ilio-inguinal nerve; G.C., Genito-crural nerve; E.C., External cutaneous nerve; A.C., Ant. crural nerve. Acc. Obt., Accessory obturator nerve; Obt., Obturator nerve; 4, 5, Lumbo-sacral trunk

Those associated with the first and second lumbar nerves are the largest.

Grey Rami Communicantes arise irregularly from the gangliated cord, and join each lumbar nerve. These grey and white Rami pass round the bodies of the vertebræ in company with the lumbar vessels within the fibrous arches from which the psoas magnus arises.

Peripheral Branches.—Some fine branches pass irregularly from the lumbar gangliated cord to join the aortic plexus on the abdominal aorta.

The Sacral Part of the Sympathetic Gangliated Cord

This portion of the gangliated cord is placed in front of the sacrum, internal to the anterior sacral foramina. Continuous above, behind the common iliac artery, with the lumbar portion of the cord, it ends below by a plexiform union with the cord of the opposite side on the front of the coccyx, in which is found the coccygeal ganglion (*g. impar*). The ganglia, usually four in number, diminish in size from above downwards.

Central Connections.—Grey Rami Communicantes connect the gangliated cord to the anterior primary divisions of the sacral and coccygeal nerves. As in the cervical region, there are no white Rami communicantes connecting the spinal nerves with the sacral gangliated cord. White Rami are, however, represented by two nerves from the anterior primary divisions of the second and third or third and fourth sacral nerves, which pass over the gangliated cord to join the pelvic plexus. They convey motor and inhibitory fibres for the pelvic viscera, vasodilator fibres for the penis or clitoris, and fibres for the prostate gland.

Peripheral Branches.—Visceral branches of small size pass from the upper ganglia to the pelvic plexus.

Parietal branches ramify over the front of the sacrum, and form a plexus with fibres from the opposite side round the middle sacral artery.

Sympathetic Plexuses

In the Neck.—Plexuses have already been described in association with the cervical gangliated cord—the carotid and cavernous plexuses; external carotid, pharyngeal, thyroid, vertebral, and subclavian plexuses. Cardiac branches pass into the thorax to join the cardiac plexus.

In the Thorax.—The main plexuses, cardiac, pulmonary, and œsophageal, are described with the vagus nerve (p. 143). The sympathetic also forms plexuses on the thoracic aorta.

In the Abdomen.—There are formed in relation to the abdominal aorta two great plexuses—the solar and aortic plexuses.

Solar and Aortic Plexuses

In the abdomen the sympathetic system forms an immense plexus around the abdominal aorta. Behind the stomach, and in close relation to the origin of the cœliac axis, is the **solar plexus,** which is continuous below with the **aortic plexus** (Fig. 44).

The **Solar Plexus** consists of three elements—the cœliac plexus, a dense meshwork of nerves surrounding the origin of the cœliac axis, and the two semilunar ganglia connected with it and placed on the crura of the diaphragm—the right one partly hidden by the inferior vena cava, and the left one by the suprarenal capsule.

The **Semilunar Ganglia** are joined by the great splanchnic nerves. Each ganglion gives off radiating branches—**inwards** to join the cœliac plexus, **upwards** to the diaphragmatic plexus, **outwards** to the suprarenal plexus, **outwards** and **downwards** to the renal plexus, **downwards** and **inwards** to the aortic plexus.

The **Cœliac Plexus,** embracing the root of the cœliac axis, contains isolated ganglia (*g. cœliaca*). It gives rise to subordinate plexuses, which travel along the branches of the artery to the abdominal viscera: hepatic, coronary, and splenic. These plexuses subdivide to form subordinate

plexuses on the branches of the arteries. They supply the œsophagus and stomach, the liver and gall bladder, stomach, duodenum, pancreas, and spleen.

The **Aortic Plexus** surrounds the abdominal aorta. Above it is constituted by tributaries from the cœliac plexus and semilunar ganglia. It receives branches from the lumbar part of the gangliated sympathetic cord, and it is continuous below with the **hypogastric plexus,** in front of the sacral promontory, by means of streams of nerve fibres (the **hypogastric nerves**) which pass down in front of and behind the bifurcation of the aorta.

Subordinate Plexuses are derived from the aortic plexus, —associated with the visceral branches of the abdominal aorta.

The **Superior Mesenteric Plexus** surrounds the superior mesenteric artery. The **Aortico-renal Ganglion** lies on each side of the root of the vessel. Accompanying the artery and its branches, this plexus is distributed to the small intestine, cœcum, vermiform appendix, ascending and transverse colon.

The **Inferior Mesenteric Plexus** surrounds the inferior mesenteric artery and its branches. It supplies the descending colon, pelvic colon, and the upper part of the rectum.

The **Spermatic Plexus** in the male surrounds the spermatic artery. It receives additional fibres from the renal plexus, and supplies the spermatic cord and testicle.

The **Ovarian Plexus** in the female surrounds the ovarian artery, and supplies the ovary and Fallopian tube. It forms communications with the uterine plexus, and sends fibres to the uterus.

The **Suprarenal Plexus** accompanies the middle capsular artery to the suprarenal capsule. It is joined by many fibres from the semilunar ganglion, and from the renal plexus.

The **Renal Plexus** extends outwards to the kidney along the renal vessels. It is reinforced by branches from the semilunar ganglion, and is connected above with the

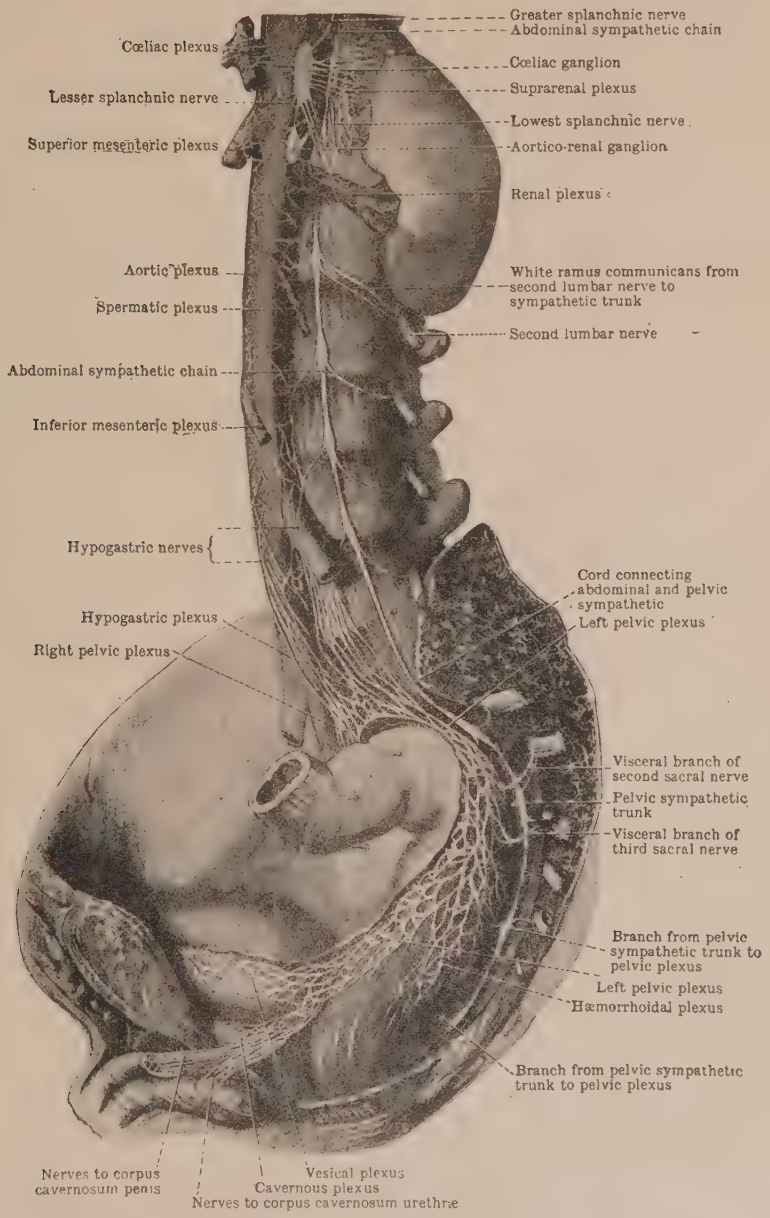


FIG. 45.—THE SYMPATHETIC IN THE ABDOMEN AND PELVIS.

suprarenal and below with the spermatic (or ovarian) plexus.

The **Hypogastric Nerves** connect the aortic plexus with the hypogastric plexus.

The **hypogastric plexus**, median in position, lies in front of the sacral promontory and behind the pelvic colon. It separates into two lateral halves—the **pelvic plexuses**—which accompany the internal iliac arteries and their branches, to be distributed to the pelvic viscera.

The **Pelvic Plexus** proceeds forwards in the side wall of the pelvis, lying in the extra-peritoneal tissue, and surrounding the internal iliac artery and its branches. It ends as the **cavernous plexus** of the penis or clitoris (Fig. 45).

The pelvic plexus is joined by grey fibres from the upper part of the sacral portion of the gangliated cord, and by **two white Rami communicantes** from the second and third, or third and fourth sacral nerves. These white Rami pass direct to the plexus, and are not connected with the gangliated cord.

Subordinate plexuses are given off from each pelvic plexus.

The **Hæmorrhoidal Plexus** accompanies the middle hæmorrhoidal artery and supplies the rectum.

The **Vesical Plexus** accompanies the vesical arteries to the bladder, and forms subordinate plexuses for the ureter, vas deferens, and vesicula seminalis.

The **Prostatic Plexus** is of large size. It supplies the prostate gland and the prostatic urethra, and a part of the vesicula seminalis.

The **Cavernous Plexus** is the termination of the prostatic plexus on each side. Numbers of nerve fibres pierce the triangular ligaments, and supply branches to the corpora cavernosa, corpus spongiosum, and the penile portion of the urethra. The cavernous plexus effects communications with the branches of the pudic nerves.

The **Uterine Plexus** accompanies the uterine artery for a short distance, and supplies the body and cervix of the

uterus. It communicates with the ovarian plexus between the layers of the broad ligament.

The **Vaginal Plexus,** mainly formed by the visceral branches from the sacral nerves, supplies the wall and mucous membrane of the vagina, and is prolonged into the **cavernous plexus** of the clitoris, which is distributed to the erectile tissue of that organ.

It is to be noted that the pelvic viscera get a double nerve supply through the spinal connections of the sympathetic system: (1) through the thoracico-lumbar stream of white Rami communicantes, which form the splanchnic nerves—the fibres being conveyed to the pelvic organs by the solar plexus, aortic plexus, hypogastric and pelvic plexuses—and (2) through the visceral nerves derived from the second and third or third and fourth sacral nerves, which join directly the pelvic plexus.

CHAPTER IV

CRANIAL NERVES

THE cranial nerves are arranged in twelve pairs, and present striking differences in their development and morphology, their distribution and functions.

Number.	Name.	Function.
1	Olfactory	Smell
2	Optic	Sight
3	Oculo-motor	Motor to muscles of orbit and eyeball
4	Trochlear	Motor to superior oblique muscle of eyeball
5	Trigeminal	Sensory to face, tongue, and teeth; motor to muscles of mastication
6	Abducent	Motor to external rectus muscle of eyeball
7	Facial	Motor to muscles of scalp and face sensory to tongue
8	Auditory	Hearing and equilibrium.
9	Glosso-pharyngeal	Sensory to tongue and pharynx
10	Vagus (or pneumo-gastric)	Sensory to pharynx, œsophagus and stomach, and respiratory organs
11	Spinal accessory	(*a*) **Accessory to vagus**: motor to the muscles of palate, pharynx; œsophagus, stomach, and intestines; inhibitory for the heart (*b*) **Spinal part**: motor to trapezius and sterno-mastoid muscles
12	Hypoglossal	Motor to muscles of the tongue

DEVELOPMENT AND MORPHOLOGY

The cranial nerves may be grouped in three classes, according to their morphology and functions. One group is associated with sense organs, comprising the

olfactory, optic, and auditory nerves. Another group is related morphologically to the system of branchial arches and clefts, comprising the trigeminal, facial, glossopharyngeal, and (part of) the vagus and spinal accessory nerves. The third group is comparable to the motor parts of the spinal nerves, comprising nerves which are motor in function—the oculo-motor, trochlear, abducent, and hypoglossal nerves (Fig. 46).

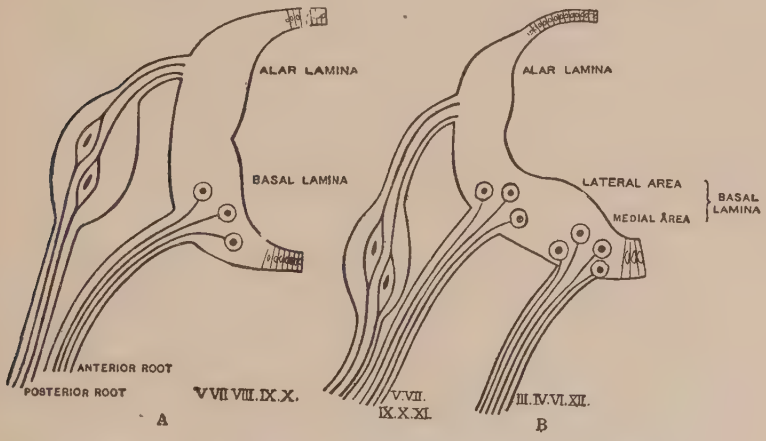


Fig. 46.—Morphology of the Spinal and Cranial Nerves.

1. Nerves Associated with Sense Organs

The olfactory, optic, and auditory nerves agree in two respects. They are associated in function with the special senses of smell, sight, and hearing, and they agree in regard to their morphology. In each case there is an outgrowth from the brain which becomes connected with an invagination from the surface of the head, resulting in the formation of a special sense organ connected by nerves with the central nervous system.

The **Olfactory Nerve.**—The olfactory bulb (Fig. 47) is derived from the **rhinencephalon,** an outgrowth from the fore brain. In many animals, as in the horse, it is a hollow outgrowth, but in man it forms a solid mass of cells connected to the

fore brain by a stalk—the olfactory peduncle. The bulb becomes connected with an invagination from the surface of the head—the **nasal pit**—which becomes the nasal cavity. The olfactory nerves form the peripheral axons of the nerve cells in the olfactory bulb, and become connected with the nasal mucous membrane. Central processes of these cells grow into relation with the brain along the olfactory peduncle.

Optic Nerve.—In the same way a hollow diverticulum arises from the under surface of the fore brain on each side, and forms the **optic vesicle**, connected to the brain and the cerebral vesicle by a hollow stalk. The vesicle extends outwards to the surface of the head, and becomes connected with an invagination from the surface epiblast, which gives rise to the **lens.** At first a plate, it becomes converted into a cup, and later is separated off from the surface in the form of a hollow vesicle. The vesicle is now associated with the optic vesicle, which itself is invaginated round the lens and forms the **optic cup.** The lens becomes converted into a solid organ by the growth of the cells of its posterior layer. The inner layer of the optic cup is converted into the retina, while the outer layer gives rise to the layer of hexagonal pigment cells. These structures are enclosed in mesoblast, which produces the other elements of the eyeball. The hollow stalk becomes solid, and by the central growth of nerve fibres from the embryonic retinal cells, the permanent optic nerve, chiasma, and tract are formed.

Auditory Nerve.—While the auditory nerve in its development bears a certain resemblance to the dorsal ganglionic root of a spinal nerve, it distinctly resembles in its general developmental features the two previous nerves. It arises as a solid ganglionic mass from the dorsal surface of the hind brain. This mass, separating from the brain, like a dorsal spinal ganglion, becomes connected with a vesicular invagination, the auditory vesicle, which like the nasal pit or the lens of the eye grows inwards from the

surface of the head, just dorsal to the first post-oral visceral cleft.

This auditory vesicle becomes the inner ear or **membranous labyrinth**, giving rise to the saccule and utricle, the ductus endolymphaticus, the scala media of the cochlea, and the three semicircular canals (Fig. 59). The **auditory ganglion,** through its peripheral nerve fibres, becomes connected with these various elements of the labyrinth. Through its central fibres it is related to the hind brain and the acoustic centres.

2. Nerves Associated with Visceral Arches

In a primitive condition each branchial arch possesses a nerve which is called trematic, and which gives off a

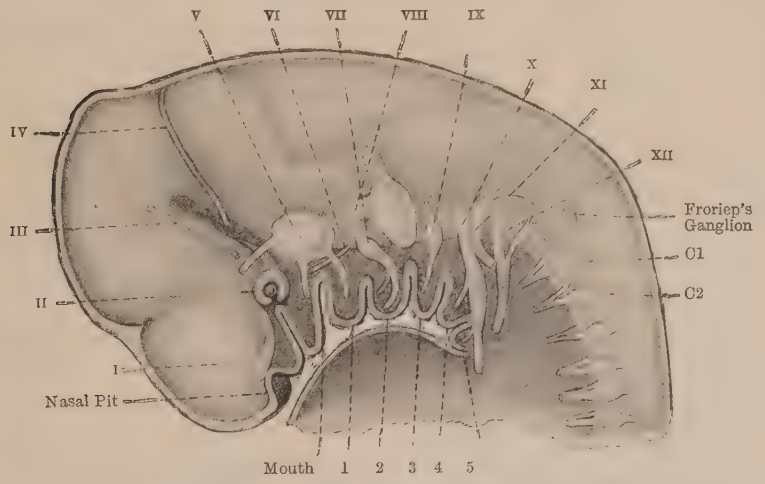


Fig. 47.—Embryo Head, showing Cranial Nerves and Gill Arches.

secondary branch, the prætrematic branch, supplying the hinder border of the previous arch.

Each typical branchial nerve is likewise provided with a dorsal ganglionic afferent root and a ventral efferent root, like a spinal nerve. The ventral root arises from the lateral aspect of the hind brain. The nerves in this

category include the fifth, seventh, ninth, tenth, and part of the eleventh cranial nerves (Figs. 46, 47).

The **trigeminal** nerve is the branchial nerve of the first post-oral visceral arch. Of its three parts the mandibular nerve is the trematic branch, the maxillary nerve the prætrematic branch, while the ophthalmic nerve represents an additional branch which is carried forwards to the more anterior parts of the head.

The **Facial** nerve is the trematic nerve of the second post-oral branchial arch. The **pars intermedia** and **geniculate ganglion** represent its afferent ganglionic root, and the **chorda tympani** is possibly its prætrematic branch.

The **Glosso-pharyngeal** nerve is the branchial nerve of the third post-oral visceral arch.

The **Vagus** and the **accessory part** of the spinal accessory nerves, while largely concerned with the innervation of other important organs, are related also to the fourth and fifth branchial arches, through the laryngeal nerves, of which the **superior laryngeal nerve** probably represents the nerve of the fourth, and the **inferior laryngeal nerve** represents that of the fifth arch.

3. Nerves Comparable to the Efferent Roots of Spinal Nerves

These comprise the oculo-motor, trochlear, abducent, and hypoglossal nerves, all purely motor nerves, which arise from the surface of the hind brain by means of nerve fibres which spring from neuroblasts within its walls, in series with the nerve cells of the medullary tube which form the ventral horn of grey matter in the embryonic spinal cord, and give origin to the ventral motor roots of the spinal nerves (Fig. 46).

Description of the Cranial Nerves

I. The Olfactory Nerve

This nerve consists of a series of twenty or twenty-five fine branches which arise from the olfactory bulb (Fig. 48).

They are non-medullated. They pierce the cribriform plate of the ethmoid bone and are distributed as a fine plexus over the upper part of the nasal septum and outer wall of the nasal cavity. They are only supplied to a small area on each wall of the nose.

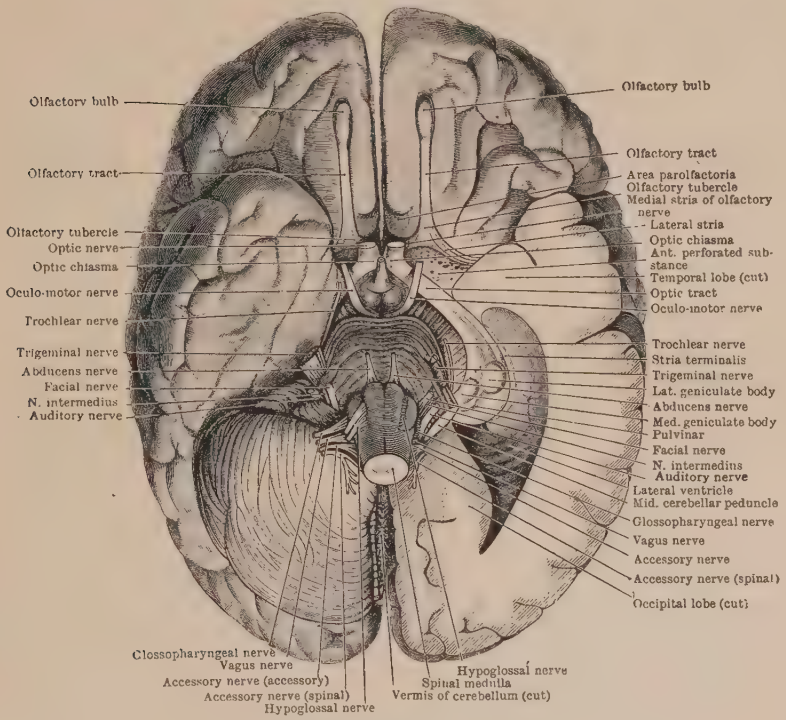


FIG. 48.—Base of Brain.

II. The Optic Nerve

This nerve arises from the optic commissure, which is formed by the union of the optic tracts (Fig. 48). The optic tract springs from the corpora quadrigemina and optic thalamus, winds round the crus cerebri, and in the base of the brain unites with the opposite tract to form the **optic commissure** or **chiasma.** This is placed within

the circle of Willis, in front of the pituitary body. It lies in the optic groove on the body of the sphenoid bone.

The optic nerve arises from each end of the commissure. In company with the ophthalmic artery it passes through the optic foramen into the cavity of the orbit (Fig. 49).

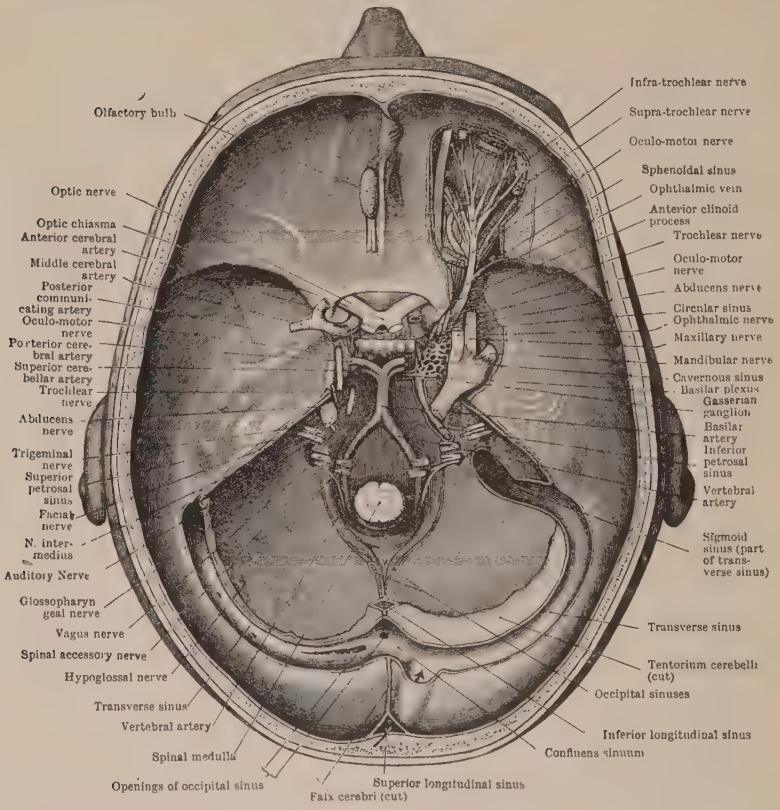


FIG. 49.—Base of the Skull, showing the Course of the Cranial Nerves.

Surrounded by the ocular muscles and imbedded in fat, it passes forwards and outwards to the eyeball, whose sclerotic and choroid coats it pierces about one-eighth of an inch to the inner side of the axis of the eyeball. Its fibres give rise to the **optic disc**, and spread out over the inner surface of the retina.

Decussation of the Optic Commissure (Fig. 49). There is a semi-decussation of the fibres of the optic tract in the commissure, so that the innervation of each eyeball is supplied by both optic tracts. In addition, at the back of the commissure, a tract occurs, in the form of **Gudden's commissure,** which connects together the two internal geniculate bodies of the optic thalami.

III. The Oculo-motor Nerve

This nerve takes origin from the oculo-motor sulcus on the median side of the crus cerebri and in front of the Pons Varolii (Fig. 48). Passing forward between the superior cerebellar and posterior cerebral arteries it pierces the dura mater in the middle fossa of the skull, and passes through the outer wall of the cavernous sinus. It enters the orbit through the sphenoidal fissure, after passing,

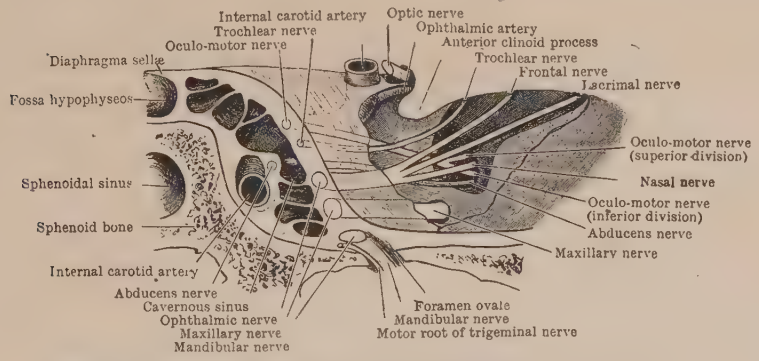


FIG. 50.—Nerves in relation to the Cavernous Sinus and the Sphenoidal Fissure.

with the nasal and sixth nerves, between the two heads of the external rectus muscle. It divides in the fissure into superior and inferior divisions, between which the nasal nerve passes (Fig. 50).

The **superior** division at once divides into two branches for the supply of the levator palpebræ superioris, and superior rectus muscles.

The **inferior** division passes forwards and supplies branches beneath the optic nerve to the internal and inferior recti muscles, and to the obliquus inferior. The nerve to the last-named muscle gives rise to the **short** (efferent) root of the **lecticular** or **ciliary ganglion** (Fig. 51).

IV. The Trochlear Nerve (n. Patheticus)

This is the nerve to the obliquus superior muscle of the eyeball.

It takes origin from the dorsal surface of the mid brain and winds round the outer side of the crus cerebri (Fig. 48) to reach its under surface, where it appears in the angle between the temporal lobe, the crus cerebri, and the Pons Varolii. Passing forward it pierces the free edge of the ten-

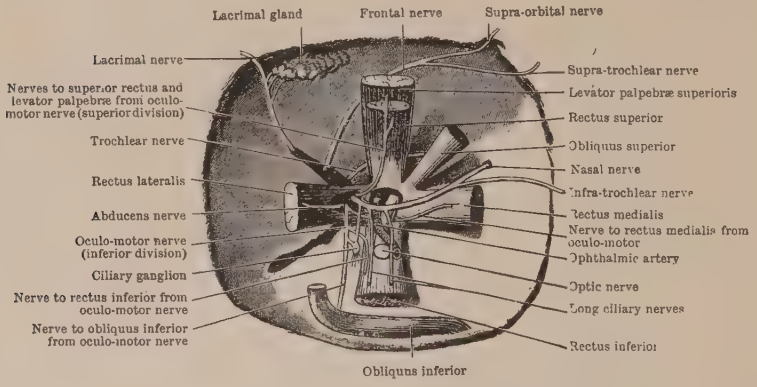


FIG. 51.—Distribution of Nerves within the Orbit.

torium cerebelli, just behind the oculo-motor nerve (Fig. 49). It then courses through the outer wall of the cavernous sinus. to the sphenoidal fissure, and enters the orbit at the inner end of that fissure above all the muscles. It enters the *orbital* surface of the obliquus superior (all the other muscles in the orbit are supplied on their *ocular* surfaces) (Figs. 50, 51).

V. The Trigeminal Nerve

This is the chief sensory nerve for the face, anterior part of the scalp, nasal and oral cavities, and teeth. It is also the motor nerve to the muscles of mastication

It takes origin from the brain by two roots, which emerge from the lateral part of the Pons Varolii. The large afferent root is internal, the much smaller efferent root is external in position at their origin (Fig. 48). As they proceed forwards the efferent root comes to lie underneath the afferent root. Passing under the tentorium cerebelli

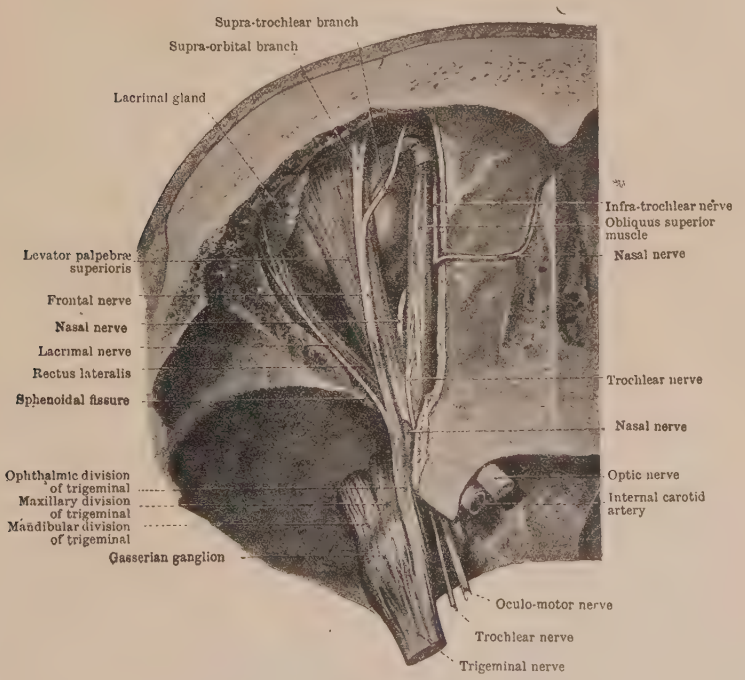


FIG. 52.—The Nerves of the Orbit from above.

the roots enter a cul-de-sac of the dura mater known as the **Cavum Meckelii**, lying on the apex of the petrous portion of the temporal bone. Here the afferent root is provided with a large flattened ganglion—the **Gasserian ganglion**—

from which three large trunks arise: the **ophthalmic, maxillary,** and **mandibular** nerves. The small efferent root becomes incorporated with the mandibular trunk. These three nerves radiate from the Gasserian ganglion, and leave the cranial cavity after a short course in the dura mater (Fig. 49).

A. The **Ophthalmic Division** (Fig. 50) is directed forwards and upwards in the outer wall of the cavernous sinus, below the third and fourth nerves, to the sphenoidal fissure. In its course it is joined by slender filaments from the cavernous plexus of the sympathetic. It gives off a small recurrent branch to the tentorium cerebelli, and it supplies minute branches to the third, fourth, and sixth nerves.

Reaching the sphenoidal fissure, the nerve divides into three trunks—lacrymal, frontal, and nasal (Fig. 52).

a. The **Lacrymal Nerve** enters the orbit through the outer angle of the sphenoidal fissure above the orbital muscles. Accompanied by the lacrymal artery it passes to the front of the orbit to supply the lacrymal gland. It gives off small branches to the skin of the upper eyelid. It communicates in its course with the orbital or temporo-malar branch of the maxillary nerve.

b. The **Frontal Nerve** passes through the central part of the sphenoidal fissure, also above all the muscles, immediately beneath the periosteum of the roof of the orbit. It divides into a smaller branch, the supra-trochlear, and a larger branch, the supra-orbital (Figs. 52, 53, 54).

The **Supra-trochlear Nerve** passes forwards over the pulley of the obliquus superior muscle, and leaves the orbit at its upper and inner angle. It supplies branches to the conjunctiva and skin of the upper eyelid, and is finally distributed to the skin of the forehead. It communicates in the orbit with the infra-trochlear branch of the nasal nerve.

The **Supra-orbital Nerve** leaves the orbit through the supra-orbital foramen. After supplying branches to the

conjunctiva and skin of the upper eyelid, it divides into branches for the supply of the skin of the forehead and scalp (Fig. 54).

c. The **Nasal Nerve** enters the orbit at the inner angle of the sphenoidal fissure. It passes between the two divisions of the third nerve, and between the two heads of the external rectus muscle. It then courses obliquely forwards and inwards across the orbit, between the optic nerve and the superior rectus muscle (Fig. 52), and between the obliquus superior and internal rectus, to reach the anterior ethmoidal foramen. It passes through this foramen, and lies next on the cribriform plate of the ethmoid bone, under cover of the olfactory bulb. It passes through the nasal fissure into the nasal cavity, and divides into median and lateral branches. The median branch is distributed to the mucous membrane over the fore part of the nasal septum. The lateral branch proceeds along the outer wall of the nasal cavity, supplying branches to the mucous membrane on the way. It ends as a branch which passes through a foramen between the nasal bone and lateral cartilage of the nose, and is distributed to the skin of the tip and ala of the nose (Fig. 53).

Collateral Branches.—In the orbit the nasal nerve gives off a series of three branches. 1. As it lies external to the optic nerve it gives off the **long root** of the lenticular or ciliary ganglion. 2. As it crosses the optic nerve **two long ciliary** branches arise which proceed forwards along the optic nerve to the eyeball. 3. As it lies internal to the optic nerve it gives off the **infra-trochlear** nerve, which passes forwards to the face under the pulley of the superior oblique muscle. This nerve communicates in the orbit with the supra-trochlear nerve. On the face the infra-trochlear nerve supplies the skin of the bridge of the nose (Fig. 53).

Ciliary Ganglion.—This is a small reddish ganglion which is placed between the external rectus muscle and the optic nerve, just in front of the ophthalmic artery. It has three

roots—a *long* (afferent) root from the nasal nerve, a *short* (efferent) root derived from the branch of the third nerve to the inferior oblique muscle, and a *sympathetic* root which comes from the cavernous plexus of the sympathetic. This root is often incorporated with the long root. The ganglion supplies twelve to fifteen **small ciliary** nerves to

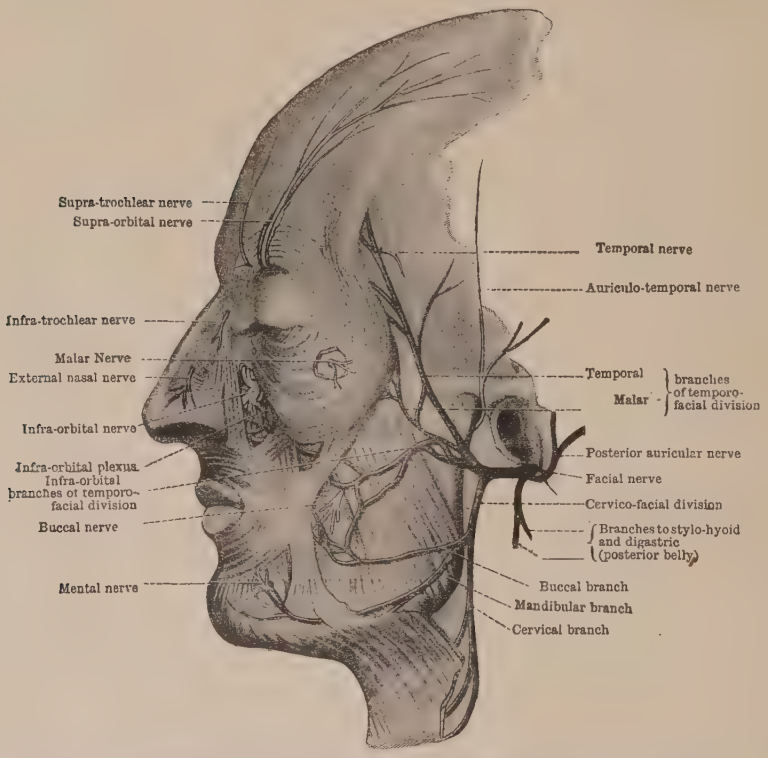


FIG. 53.—The Distribution of the Facial and Trigeminal Nerves on the Face.

the eyeball. The motor fibres supply the ciliary muscle, and the constrictor (circular) fibres of the iris.

The sympathetic supplies the radial (dilator) fibres of the iris.

B. The **Maxillary Division** (Fig. 55) passes horizontally forwards from the Gasserian ganglion, through the outer wall of the cavernous sinus, to the foramen rotundum.

It is directed across the spheno-maxillary fossa to the spheno-maxillary fissure, by which it reaches the floor of the orbit. Under the name of the **infra-orbital nerve** it proceeds forwards in the infra-orbital groove and canal

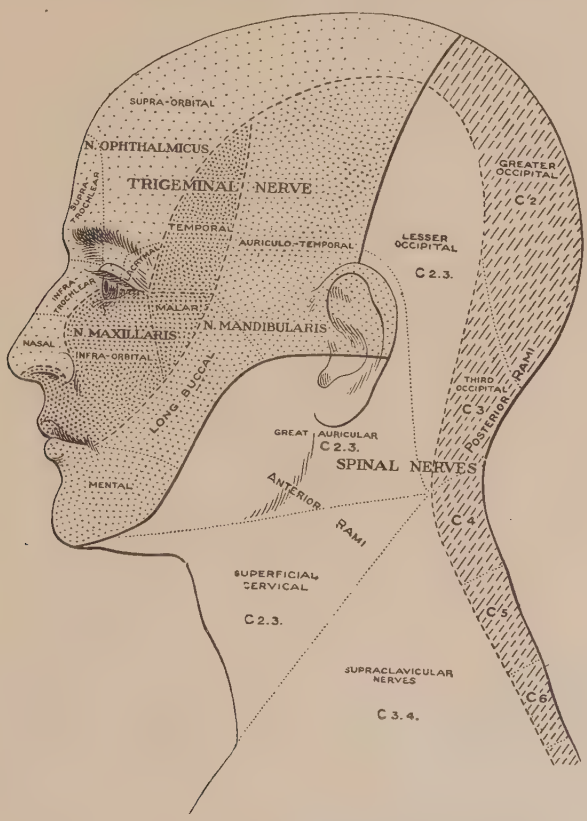


Fig. 54.—Innervation of the Skin of the Head and Neck.

to the face, which it reaches through the infra-orbital foramen. It is accompanied through the floor of the orbit by the infra-orbital branch of the internal maxillary artery. Its terminal branches are in three sets—**palpebral, nasal, and labial**—radiating to supply the skin of the lower eyelid, the side of the nose, and the upper lip (Figs. 53, 54). They

form a considerable infra-orbital plexus with branches of the facial nerve.

Collateral Branches (Fig. 55).—(1) *In the cranial cavity* a small **recurrent** or meningeal branch arises for the supply of the dura mater and the middle meningeal artery.

(2) *In the spheno-maxillary fossa* three series of branches arise.

a. The **orbital** or temporo-malar nerve passes into the

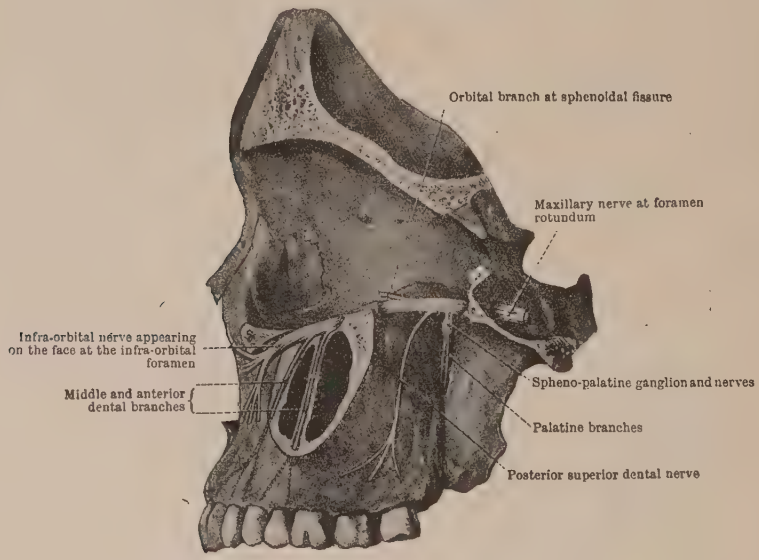


FIG. 55.—Course of the Maxillary Nerve.

cavity of the orbit through the spheno-maxillary fissure. It courses forwards in the outer wall of the orbit, communicating on its way with the lacrymal nerve, and passes through the orbital canal in the malar bone. In this canal it divides into temporal and malar branches.

The **temporal branch** emerges in the temporal fossa and winds round the anterior border of the temporal muscle. Piercing the temporal fascia, it supplies the skin over the anterior part of the temporal fossa.

The **malar branch** pierces the malar bone and appears on the cheek, the skin of which it supplies (Fig. 53).

b. The **Posterior Dental Nerve** arises in the spheno-maxillary fossa, and passes downwards and outwards through the pterygo-maxillary fissure on to the surface of the upper jaw. After supplying branches to the gum and the skin of the cheek it is distributed to the molar teeth. The branches reach the sockets of the teeth through small foramina in the alveolar border of the jaw.

c. Two **spheno-palatine** nerves pass down to join Meckel's ganglion in the spheno-maxillary fossa.

(3) *In the infra-orbital canal* the infra-orbital nerve gives off the **middle** and **anterior superior dental** nerve. In some cases they arise as a single branch which subdivides in its course.

These two nerves pass through osseous canals in the wall of the maxillary antrum to reach the alveolar border of the jaw. The middle dental nerve supplies the præmolar teeth ; the anterior dental nerve is distributed to the incisor and bicuspid teeth. All the dental nerves form together fine plexiform loops from which branches pass to the teeth and the lining membrane of the maxillary antrum.

The **spheno-palatine** or **Meckel's ganglion** is a reddish ganglion about one-fifth of an inch in diameter, which occupies the upper part of the spheno-maxillary fossa. It is provided with motor, sympathetic, and sensory roots. The motor and sympathetic roots are provided by the **vidian nerve.** This nerve is formed in the cranial cavity by two nerves which unite over the foramen lacerum medium. The **great superficial petrosal nerve** is a branch of the geniculate ganglion of the facial, and emerges from the petrous portion of the temporal bone through the Hiatus Fallopii. This is the motor root. It is joined by the **great deep petrosal nerve,** a branch of the cavernous sympathetic plexus on the internal carotid artery. The vidian nerve thus formed passes through the vidian canal to the spheno-maxillary fossa, where it joins the ganglion.

The **spheno-palatine branches** of the maxillary nerve form the sensory roots of the ganglion. These nerves are not wholly incorporated in the ganglion, many fibres passing directly into the nasal and palatine branches.

The ganglion gives off branches which pass *backwards*, *downwards*, and *inwards*.

The pterygo-palatine or **pharyngeal** branch passes backwards through the pterygo-palatine foramen to supply the mucous membrane of the roof of the pharynx.

Three **posterior palatine** nerves pass downwards through the palatine canals. The **large posterior palatine** nerve descends to the hard palate, where it is directed forwards to supply the mucous membrane of the roof of the mouth. It communicates anteriorly with the naso-palatine nerve. This nerve supplies an **inferior nasal branch**, which ramifies in the mucous membrane over the inferior turbinate bone.

The **Small Posterior Palatine** nerve descends to the soft palate, and supplies the mucous membrane of the soft palate, uvula, and tonsil. The **external** or **least posterior palatine** nerve is distributed also to the soft palate, uvula, and tonsil.

Two branches pass inwards from the ganglion through the spheno-palatine foramen to the nasal cavity.

The **Superior Nasal** nerve is a small nerve which supplies the mucous membrane over the superior and middle turbinate bones.

The **Naso-palatine** nerve is a considerable branch. It crosses the roof of the nasal cavity, and proceeds obliquely downwards and forwards along the nasal septum (grooving the vomer in its course). It supplies branches to the mucous membrane of the nasal septum, and reaches the front of the hard palate through the foramina of Scarpa in the incisor foramen. The two nerves are united here by a fine plexus, and are distributed to the mucous membrane of the fore part of the hard palate. They communicate posteriorly with the large posterior palatine nerves.

C. The **Mandibular Division** (Fig. 56) arises from the outer

part of the Gasserian ganglion (Fig. 49). It is the largest of the branches of the trigeminal nerve. The nerve is formed by the union of the trunk from the Gasserian ganglion with the small efferent root of the nerve. They pass through the foramen ovale, and unite together immediately below it, to form a short trunk which very soon subdivides into two unequal parts, a small anterior and a large

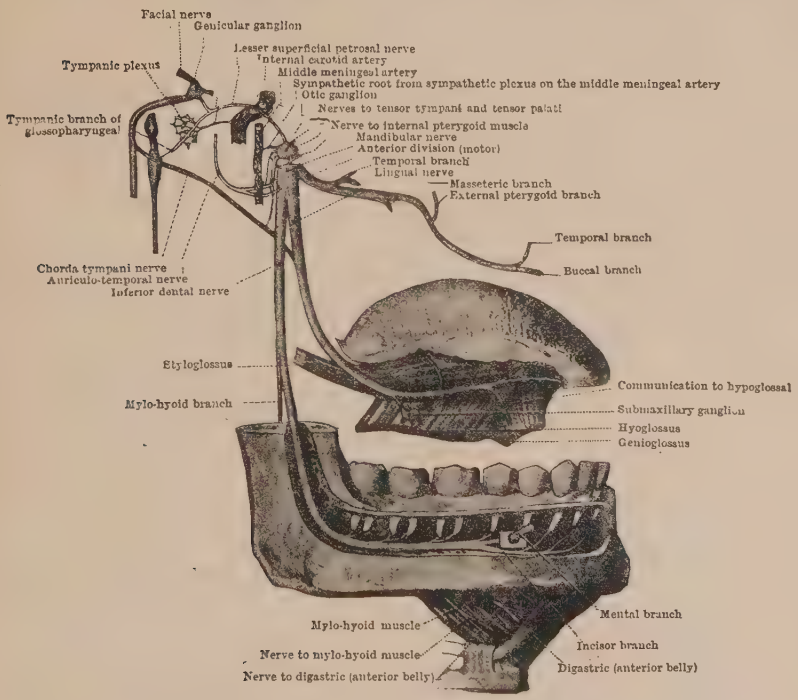


FIG. 56.—Distribution of the Mandibular Nerve.

posterior part. Each contains both afferent and efferent fibres, but the anterior division is chiefly efferent, and the posterior division is chiefly afferent in character.

The **Undivided Nerve** gives off two branches (Fig. 56). A **recurrent branch** enters the skull through the foramen spinosum, and is distributed to the dura mater and the lining membrane of the mastoid air cells. The nerve

to the **internal pterygoid** muscle passes downwards and forwards to enter the border of the muscle. It passes over, and is connected with the otic ganglion in its course.

The small **anterior division** of the nerve supplies the following branches: two **temporal** nerves to the temporal muscle, which pass above the external pterygoid muscle to reach the deep surface of the temporal muscle; a nerve to the **masseter,** which passes outwards through the sigmoid notch; a nerve to the **external pterygoid** muscle and the **long buccal** nerve. This appears in the zygomatic fossa between the two heads of the external pterygoid muscle, and passes obliquely downwards and forwards beyond the anterior border of the masseter, to lie on the buccinator muscle. It supplies the skin of the cheek, and, piercing the buccinator muscle, it also innervates the mucous membrane of the mouth (Fig. 54).

The long buccal nerve often supplies a third deep temporal branch for the temporal muscle.

The large **posterior division** of the nerve separates into three branches. It gives off the auriculo-temporal nerve, and divides into the lingual and inferior dental nerves.

a. The **Auriculo-temporal** nerve arises by two roots which embrace the middle meningeal artery. It passes behind the neck of the lower jaw, in company with the internal maxillary artery, and then proceeds upwards to the scalp through the parotid gland, in company with the superficial temporal artery.

It is distributed as follows:

(1) Each root of the nerve receives connections from the otic ganglion.

(2) Branches are supplied to the parotid gland.

(3) Branches supply the epithelium of the external auditory meatus and membrana tympani, and the upper part of the pinna.

(4) The terminal branches of the nerve supply the skin of the scalp over the temporal fossa (Fig. 54).

(5) Communications are effected with the facial nerve in the parotid gland and over the temporal fossa.

b. The **Lingual** nerve (Fig. 56) passes downwards beneath the pterygoid muscles and the ramus of the lower jaw to the floor of the mouth. Crossing the floor of the mouth between the gum and the side of the tongue, it is distributed to the mucous membrane of the tongue in its anterior two-thirds.

The lingual nerve is joined soon after its origin in the zygomatic fossa by the **chorda tympani** branch of the facial nerve. In its course the lingual nerve supplies branches to the mucous membrane of the mouth. As it crosses the floor of the mouth on the hyo-glossus muscle it communicates by a series of loops with the hypoglossal nerve.

The **submaxillary ganglion** belongs to the lingual nerve. It is a small reddish ganglion suspended from the lingual nerve in its course across the floor of the mouth. It receives **roots** from the lingual and chorda tympani nerves and from the sympathetic plexus on the facial artery, and it gives branches to the submaxillary and sublingual salivary glands, and Wharton's duct.

c. The **Inferior Dental** nerve (Fig. 56) is larger than the lingual. It lies behind it and passes downwards to the inferior dental foramen. Passing into the inferior dental canal, it is distributed to the teeth of the lower jaw, giving off fine branches, which form plexiform loops, before being finally distributed to the teeth.

It gives off the following branches:

(1) **Mylo-hyoid** branch.—This nerve arises before the main trunk enters the inferior dental canal. Occupying the mylo-hyoid groove of the lower jaw, it reaches the superficial surface of the mylo-hyoid muscle and supplies it and the anterior belly of the digastric muscle.

(2) **Mental** branch.—In the inferior dental canal the inferior dental nerve, besides supplying the teeth, gives off a cutaneous branch—the mental nerve—which passes

through the mental foramen of the lower jaw to supply the skin of the lower lip and chin (Figs. 53, 56).

(3) **Incisor** branch.—Beyond the origin of the mental nerve the inferior dental nerve is continued as the **incisor** branch, for the supply of the incisor and canine teeth.

The **otic ganglion**, associated with the mandibular nerve, is placed on its deep surface just below the foramen ovale (Fig. 56).

It possesses three roots: (1) **Motor,** from the nerve to the internal pterygoid muscle; (2) **Sensory**, from the **small superficial petrosal** nerve, from the tympanic plexus, which is formed by the combination of the tympanic branch of the glosso-pharyngeal nerve with a branch from the geniculate ganglion of the facial nerve; and (3) a **Sympathetic** root from the plexus on the middle meningeal artery.

The branches from the ganglion are **communicating** branches to the vidian nerve, to each root of the **auriculo-temporal** nerve, and to the **chorda tympani**; and **motor** branches to the tensor tympani and tensor palati muscles.

VI. Abducent Nerve

This small nerve issues from the brain at the posterior border of the Pons Varolii, just in front of the medulla oblongata (Fig. 48). It pierces the dura mater of the posterior fossa of the skull alongside the dorsum sellae (Fig. 49), and passes forward to the sphenoidal fissure in the inner wall of the cavernous sinus, lying on the outer side of the internal carotid artery.

It enters the orbit through the inner end of the sphenoidal fissure, and between the two heads of the external rectus muscle. It is placed in this course below the third and nasal nerves.

It has **communications** as it lies in relation to the cavernous sinus with two nerves—the ophthalmic, and the cavernous plexus on the internal carotid artery.

It is finally distributed to the external rectus muscle of

the eyeball, which it enters on its inner (ocular) surface (Fig. 51).

VII. Facial Nerve

The facial nerve emerges from the brain at the posterior border of the Pons Varolii, at its junction with the restiform body (Fig. 48). It lies internal to the pars intermedia and the auditory nerve.

The nerve passes outwards through the internal auditory meatus, proceeds through the petrous and mastoid portions of the temporal bone, lying in the aqueduct of Fallopius,

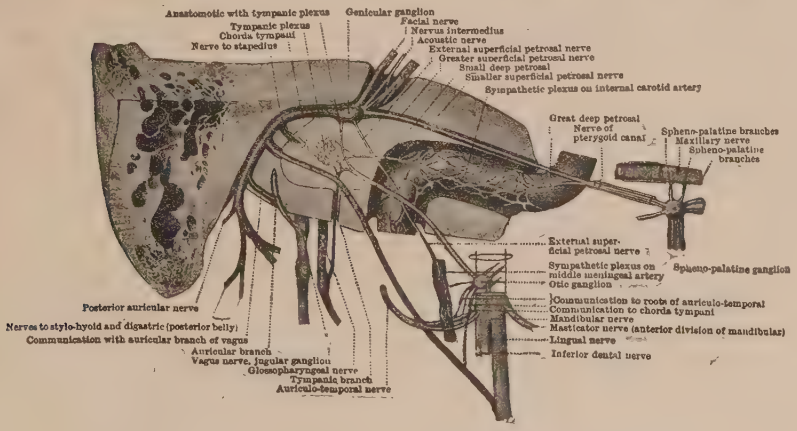


FIG. 57.—The Facial Nerve in the Temporal Bone.

emerges through the stylomastoid foramen, and passes forward through the parotid gland to supply the muscles of the face (Fig. 57).

While in the meatus the nerve lies on the auditory nerve, the **Pars Intermedia** intervening. **In the aqueduct of Fallopius** the nerve is related at first to the inner wall of the tympanum, and afterwards passes downward behind the tympanum, in relation to the inner wall of the mastoid antrum. **In the parotid gland** the nerve crosses over the temporo-maxillary vein and the external carotid artery.

Branches and Communications.—(1) **In the internal**

auditory meatus the facial nerve receives communicating branches from the pars intermedia and the auditory nerve (Fig. 59).

(2) **In the aqueduct of Fallopius** (Fig. 57) the **geniculate ganglion** is formed at the point where the nerve bends backwards. It is an oval swelling, which received the communicating branch from the auditory nerve (by which it probably receives fibres from the pars intermedia). Three small branches arise from the ganglion.

(*a*) The **large superficial petrosal** nerve passes forward to the middle fossa of the skull through the Hiatus Fallopii. On the upper surface of the foramen lacerum medium it is joined by the **great deep petrosal** nerve, from the sympathetic plexus on the internal carotid artery, to form the **vidian** nerve, which passes through the vidian canal to join Meckel's ganglion.

(*b*) The **external superficial petrosal** nerve is a small filament which joins the sympathetic plexus on the middle meningeal artery.

(*c*) A **tympanic** branch joins the tympanic plexus, and, uniting with the tympanic branch of the glosso-pharyngeal nerve, gives rise to the **small superficial petrosal** nerve which pierces the temporal bone and joins the otic ganglion.

In the course of the nerve through the vertical part of the aqueduct of Fallopius three branches arise:

(*d*) The nerve to the **stapedius** muscle, which passes through the posterior wall of the tympanum.

(*e*) A **communicating** branch which joins the auricular branch of the vagus.

(*f*) The **chorda tympani** nerve.—This nerve crosses the membrana tympani and the handle of the malleus. It enters the tympanic cavity by the **iter chordæ posterius,** and leaves it by the **iter chordæ anterius**, to reach the zygomatic fossa. Beneath the external pterygoid muscle it joins the lingual nerve (Fig. 56), and is distributed with it to the side and dorsum of the tongue in its anterior two-thirds.

It receives a communicating branch from the otic ganglion, and contributes one root to the submaxillary ganglion.

In the neck the facial nerve supplies muscular branches to the **posterior belly of the digastric,** and the **stylohyoid** muscles; and the **posterior auricular** nerve, which passes

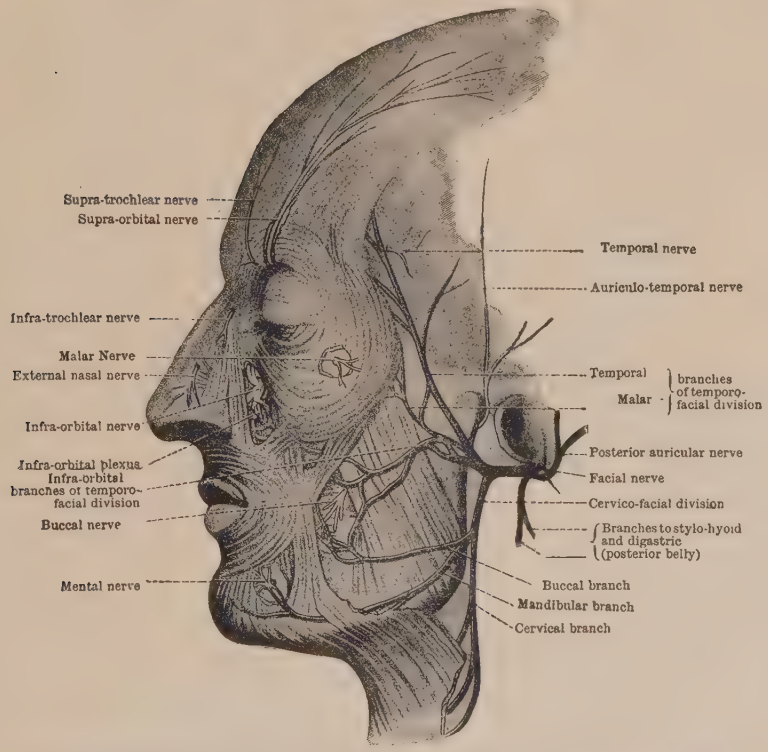


FIG. 58.—The Distribution of the Trigeminal and Facial Nerves on the Face.

upwards with the posterior auricular artery, along the anterior border of the mastoid process to supply the retrahens aurem and the occipital belly of the occipito-frontalis muscle.

In the parotid gland (Fig. 58), the nerve spreads out to form the **pes anserinus,** an irregular radiating series of

nerves, which are subdivided into a temporo-facial and a cervico-facial series.

A. The **temporo-facial division** passes to the edge of the parotid gland, from which it emerges in the form of three unequal series of nerves—temporal, malar, and infra-orbital.

(1) The **temporal** branches are the most numerous. They pass over the zygoma and end in the deep surface of the facial muscles—obicularis oculi, frontalis, corrugator supercilii, attrahens, and attollens aurem. The temporal branches communicate on the face with the following branches of the fifth cranial nerve: auriculo-temporal, temporal (of the temporo-malar), supra-orbital, and lacrimal nerves (Fig. 58).

(2) The **malar** branches are the smallest. Passing forward they supply the orbicularis oculi and zygomatic muscles, and communicate with the malar branch of the temporo-malar nerve.

(3) The **infra-orbital** nerves form a considerable **infra-orbital plexus** with the infra-orbital branch of the maxillary nerve. Branches are distributed to the orbicularis palpebrarum, buccinator, and zygomatic muscles, and to the muscles of the nose and upper lip. Besides communicating with the infra-orbital nerve additional communications are effected with the infra-trochlear and nasal nerves on the side of the nose.

B. The **cervico-facial division** also supplies three series of branches—buccal, mandibular, and cervical.

(1) The **buccal** branches supply the buccinator muscle, and other muscles of the lips. They communicate freely with the long buccal branch of the mandibular nerve.

(2) The **mandibular** (or **supra-mandibular**) branch supplies the orbicularis oris, and the depressor anguli oris, and communicates with the mental branch of the inferior dental nerve.

(3) The **cervical** (or **infra-mandibular**) branch emerges from the parotid gland near its lower end, and curves round the angle of the jaw to reach the neck, where it supplies the

platysma muscle, and has a series of loops of communications with the superficial cervical nerve.

VIII. Auditory Nerve

The auditory nerve arises from the medulla oblongata by two roots, mesial and lateral (Fig. 48). The **mesial** (vestibular) root appears between the olive and the restiform body. The **lateral** (cochlear) root winds round the outer side of the restiform body (Fig. 59).

They unite to form the nerve trunk, which passes through the internal auditory meatus, lying beneath the facial nerve

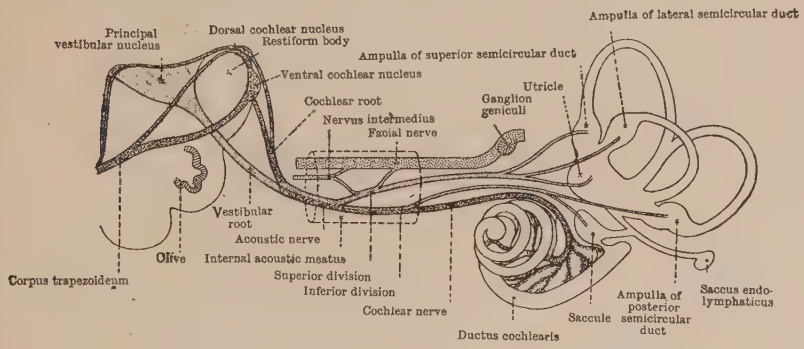


FIG. 59.—The Distribution of the Auditory Nerve.

and pars intermedia. In the meatus it separates into superior or **vestibular,** and inferior or **cochlear divisions,** each continuous respectively with the mesial and lateral roots (Fig. 49).

The **superior, vestibular, division** receives a communication from the pars intermedia, and gives off a communicating branch to the geniculate ganglion of the facial nerve. It finally gives rise to three branches, which pierce the lamina cribrosa and end in the macula acustica of the utricle, and the ampullæ of the superior and external semicircular canals.

The **inferior, cochlear,** trunk also supplies three branches—to the saccule, the posterior semicircular canal, and the

cochlea. The last-named nerve passes through the modiolus of the cochlea and is distributed along the spiral lamina to the Organ of Corti.

Both vestibular and cochlear nerves contain many nerve cells intermingled with the nerve fibres—forming the **vestibular ganglion** and the **spiral ganglion of the cochlea.**

IX. Glosso-pharyngeal Nerve

The glosso-pharyngeal nerve arises from the medulla oblongata by several roots, between the olive and the restiform body (Fig. 48). It leaves the skull through the jugular foramen along with the vagus and spinal accessory nerves, but enveloped in a separate sheath of dura mater. In the neck the nerve lies at first between the internal jugular vein and the internal carotid artery. It is directed forwards between the internal and external carotid arteries, sweeps round the stylo-pharyngeus muscle and stylo-hyoid ligament, and passes beneath the hyoglossus muscle to the tongue (Fig. 60).

Branches and Communications.—(*a*) **In the jugular foramen.** Two ganglionic enlargements occur on the nerve while in the foramen. The **jugular** (superior) ganglion is small; it does not implicate the whole nerve; it may be absent, and no branches arise from it. The **petrous** ganglion is important. Besides effecting communications with the superior cervical sympathetic ganglion, with the auricular branch of the vagus, and sometimes with the ganglion of the root of the vagus, the ganglion gives off a **tympanic branch** (Jacobsen's nerve). This passes through a small canal in the petrous bone between the jugular notch and the carotid canal, to reach the tympanum. Here it joins the **tympanic plexus,** completed by the **small deep petrosal** nerve from the carotid plexus, and by a small **tympanic** branch from the geniculate ganglion of the facial nerve. The tympanic branch of the glosso-pharyngeal unites with the branch from the

facial to form the **small superficial petrosal** nerve. This eventually joins the **otic ganglion.**

(*b*) **In the neck** the glosso-pharyngeal nerve gives off two branches—a branch to the **stylo-pharyngeus** muscle given off as the nerve curves over it, and a **pharyngeal**

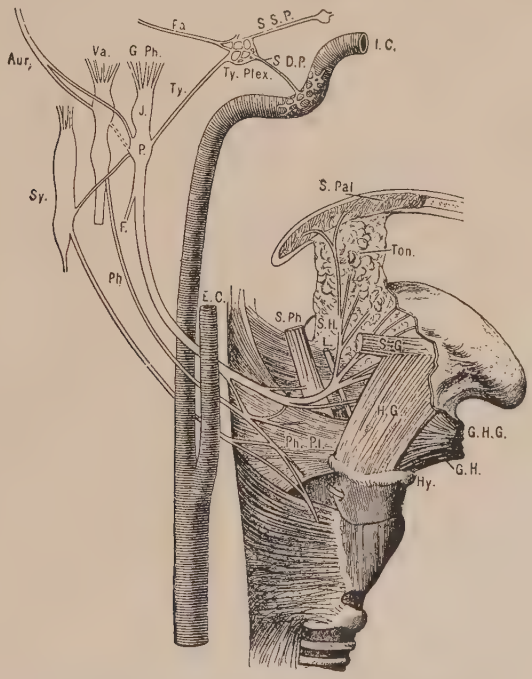


FIG. 60.—Scheme of the Distribution of the Glosso-pharyngeal Nerve.

G.Ph., Glosso-pharyngeal nerve; J., Superior, and P., Petrous ganglia; Ty., Tympanic nerve; Ty. Plex., Tympanic plexus; Fa., Root from geniculate ganglion of facial nerve; S.S.P., Lesser superficial petrosal nerve to the otic ganglion; S.D.P., small deep petrosal nerve; I.C., Internal carotid artery; Va., Vagus nerve; Aur., Auricular branch of vagus; Sy., Superior cervical sympathetic ganglion; F., Communicating branch to facial nerve; Ph., Pharyngeal branch of vagus; E.C., External carotid artery; Ph.Pl., Pharyngeal plexus; S.Ph., Stylo-pharyngeus muscle; S.H.L., Stylo-hyoid ligament; H.G., Hyoglossus; S.G., Styloglossus; Ton., Palatine tonsil; S. Pal., Soft palate; G.H.G., Genioglossus; G.H., Genio-hyoid; Hy., Hyoid bone.

branch which, along with the pharyngeal branches of the vagus and sympathetic, completes the **pharyngeal plexus.**

(*c*) The terminal branches of the nerve supply the mucous membrane of the tongue,

A **tonsillitic branch** gives rise to a plexus (*pl. circularis*) for the mucous membrane covering the tonsil, pillars of the fauces, and the soft palate.

The **lingual branches** supply the mucous membrane of the dorsum and side of the tongue in its posterior third or half, extending backwards so as to include the anterior surface of the epiglottis.

X. Vagus or Pneumogastric Nerve

This is one of the most remarkable nerves in the body. Branchial in its primary distribution, it supplies a cutaneous branch to the back of the pinna, and there is as yet no acceptable theory as to its course and distribution to organs below the diaphragm. There is still justification for the old classification of Willis, which groups the glosso-pharyngeal, vagus, and spinal accessory as one (eighth) nerve, as the three nerves are closely associated together both in origin and in distribution. The glosso-pharyngeal and vagus have a common origin, and the vagus and the accessory part of the spinal accessory nerves are intimately related to one another in their distribution to viscera.

The vagus nerve arises from the medulla oblongata (Fig. 48) by twelve to fifteen filaments just below the glosso-pharyngeal nerve. Passing outwards through the jugular foramen (Fig. 49), it enters the neck, enveloped in a sheath common to it and the spinal accessory nerve. Two ganglia are placed on this part of the nerve—one in the jugular foramen, the ganglion of the **root**; the other half an inch below it, the ganglion of the **trunk.**

The nerve proceeds vertically downwards in the neck, between and behind the large vessels—the internal jugular vein and internal carotid artery above, the internal jugular vein and common carotid artery below. **On the right side** it enters the thorax by passing in front of the first part of the subclavian artery and behind the subclavian vein. **On the left side** it passes between the left common carotid and left subclavian arteries.

In the thorax and abdomen the nerve has a different disposition on the two sides (Fig. 61).

On the right side it passes downwards between and

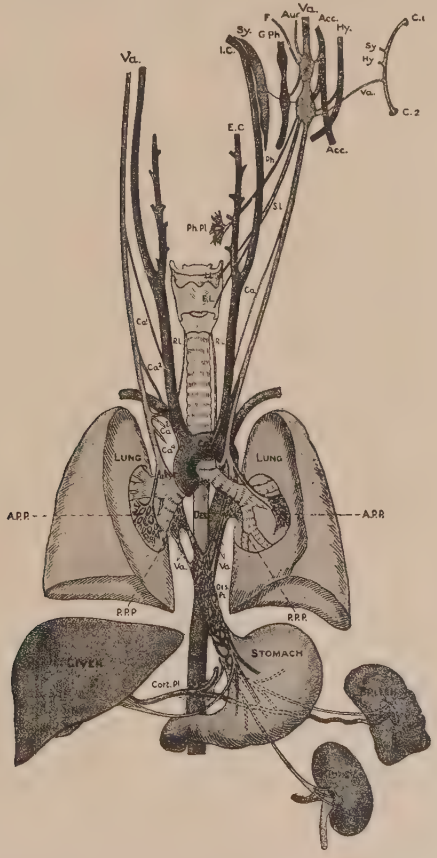


FIG. 61.—The Distribution of the Vagus Nerve.

Va., Right and left vagi; r, Ganglion jugulare and connections with Sy., Sympathetic, superior cervical ganglion; G.Ph., Glosso-pharyngeal; Acc., Accessory nerve; F., Meningeal branch; Aur., Auricular branch; Va, Connection with ganglion nodosum of vagus; Sy, Nerve to stylo-hyoid; Hy., Nerve to hyoglossus; C1, C2, Loop between the first two cervical nerves; Sy., Sympathetic, superior cervical ganglion; Acc., Accessory nerve; Ph., Pharyngeal branch; Ph.Pl., Pharyngeal plexus; S.L., Superior laryngeal nerve; I.L., Internal laryngeal branch; E.L., External laryngeal branch; I.C., Internal, and E.C., External carotid arteries; Ca1., Superior cervical cardiac branch; Ca2, Inferior cervical cardiac branch; R.L., Recurrent nerve; Ca3, Cardiac branches from recurrent nerves; Ca4, Thoracic cardiac branch (right vagus); A.P.P., Anterior, and P.P.P., Posterior pulmonary plexuses; Oes.Pl., Œsophageal plexus; Cœl.Pl., Cœliac plexus.

behind the innominate vessels, passes internal to the vena azygos major, and breaks up behind the root of the lung to form the posterior pulmonary plexus. The plexus gives off two trunks which pass obliquely downwards and inwards over the vena azygos major to the œsophagus, where they join the œsophageal plexus. Finally, the nerve continues as a single trunk, through the œsophageal opening in the diaphragm, behind the œsophagus, to supply the posterior surface of the stomach. It gives off branches to the cœliac plexus, to the splenic plexus, and to the renal plexus of the left side.

On the left side, in the superior mediastinum, the nerve lies, at first, between the left common carotid and subclavian arteries, and behind the left innominate vein. It is crossed by the phrenic nerve in this position. It then passes over the arch of the aorta, and behind the root of the lung breaks up into the posterior pulmonary plexus. From this two trunks arise which pass obliquely downwards and inwards over the descending thoracic aorta, to join the œsophageal plexus. Thereafter the nerve proceeds as a single trunk through the œsophageal opening of the diaphragm, in front of the œsophagus, into the abdomen, where it is distributed to the anterior surface of the stomach. It sends branches between the layers of the small omentum to the hepatic plexus.

Branches and Communications.—(*a*) **The Ganglia of the Vagus.**

(1) **The ganglion of the root,** placed in the jugular foramen, has communications with the superior cervical ganglion of the sympathetic, and with the petrous ganglion of the glosso-pharyngeal; it also receives fibres from the accessory part of the spinal accessory nerve. It gives off two branches—a recurrent branch and an auricular branch.

The **recurrent** branch supplies the dura mater of the posterior fossa of the skull.

The **auricular** branch (Arnold's nerve) may represent a

branchial nerve. It passes backwards to a small foramen near the root of the styloid process, pierces the temporal bone, and, emerging between the external auditory meatus and the mastoid process, divides into two branches, of which one supplies the skin of the lower part of the deep surface of the pinna (the "Alderman's" nerve), while the other joins the posterior auricular nerve. The auricular branch receives a communicating branch from the petrous ganglion of the glosso-pharyngeal nerve, and in the substance of the temporal bone communicates with the facial nerve.

(2) The **ganglion of the trunk,** placed just below the jugular foramen, is an oval swelling on the nerve. It is joined by the major part of the accessory portion of the spinal accessory nerve. Some of the fibres join the ganglion and are incorporated in the vagus for the supply of the larynx and heart. Many of the fibres pass over the ganglion and are continued directly into the pharyngeal and superior laryngeal branches.

This ganglion, besides its connection with the spinal accessory nerve, communicates with the hypoglossal, superior cervical sympathetic ganglion, and with the loop between the first two cervical nerves. It gives off two branches, the pharyngeal and superior laryngeal nerves.

The **pharyngeal** branch passes obliquely downwards and inwards between the internal and external carotid arteries to the wall of the pharynx, where it combines with the pharyngeal branches of the glosso-pharyngeal and sympathetic nerves to form the **pharyngeal plexus,** for the supply of the muscles and mucous membrane of the pharynx.

The **superior laryngeal** nerve passes obliquely downwards and inwards behind the carotid arteries towards the pharynx. It divides into two branches, internal and external laryngeal.

The **internal laryngeal** nerve, the larger branch, passes forwards to the interval between the hyoid bone and

thyroid cartilage, and, piercing the thyro-hyoid membrane, is distributed to the mucous membrane of the larynx. Beneath the ala of the thyroid cartilage it forms loops of communication with the inferior laryngeal nerve.

The **external laryngeal** nerve, a small nerve, proceeds over the surface of the pharynx and larynx to end in the crico-thyroid muscle. It supplies a branch to the inferior constrictor muscle of the pharynx.

(*b*) **Branches of the Vagus in the Neck.**—Two cardiac branches arise, upper and lower, and on the right side the recurrent or inferior laryngeal nerve.

Cardiac branches.—These are slender nerves which proceed downwards into the thorax. The two nerves of the right side join the deep cardiac plexus. On the left side the superior nerve joins the deep plexus, while the inferior nerve passes in front of the aortic arch to join the superficial cardiac plexus.

The **right recurrent** or **inferior laryngeal** nerve arises from the vagus at the root of the neck. It hooks round the first part of the subclavian artery, and ascends to the larynx behind the internal jugular vein and common carotid artery. It then lies to the inner side of the artery between the œsophagus and trachea, and passing under the inferior constrictor muscle and the ala of the thyroid cartilage, it ends by supplying the intrinsic muscles of the larynx (except the crico-thyroid). It supplies branches to the right half of the deep cardiac plexus, to the muscular fibres of the trachea and œsophagus, and to the inferior constrictor muscle of the pharynx. It also communicates with the inferior cervical sympathetic ganglion; and beneath the ala of the thyroid cartilage, with the internal laryngeal nerve.

(*c*) **Branches of the Vagus in the Thorax.**—The **right** vagus nerve gives off **cardiac** branches which join the deep cardiac plexus. On the left side no cardiac branches arise directly from the trunk of the nerve.

The **left recurrent** or **inferior laryngeal** nerve arises from

the left vagus just below the arch of the aorta. It hooks round the arch and round the **ligamentum ductus arteriosi,** and ascends in the interval between the trachea and œsophagus into the neck, where its course and distribution are the same as on the right side. In the thorax it gives off **cardiac** branches which join the left half of the deep cardiac plexus.

Thoracic Plexuses

The vagi nerves are engaged in the thorax in the formaion of three important plexuses—pulmonary, cardiac, and œsophageal.

The Pulmonary Plexuses

The vagus nerve breaks up on each side behind the root of the lung into a plexus of fibres—the **posterior pulmonary plexus**—which is joined by fibres from the third and fourth thoracic ganglia of the sympathetic. Above the root of the lung on each side each vagus gives off a stream of fibres which pass in front of the root of the lung to form the **anterior pulmonary plexus.** This is joined by fibres from the deep cardiac plexus.

The branches from the pulmonary plexuses are distributed to the lungs along with the pulmonary vessels (Fig. 61).

Cardiac Plexuses

There are two plexuses associated with the heart—superficial and deep (Fig. 62).

The **superficial cardiac plexus** is placed between the aortic arch and the bifurcation of the pulmonary artery. It is formed by the upper cervical sympathetic cardiac branch on the left side, and the lower cervical cardiac branch of the left vagus nerve. It contains a small ganglion —the ganglion of Wrisberg—and from the plexus nerves are distributed to the coronary plexuses. It supplies branches also which pass to the deep cardiac plexus.

The **deep cardiac plexus** surrounds the lower end of the trachea. It consists of two lateral halves, joined together by connecting plexiform fibres, in front of and behind the

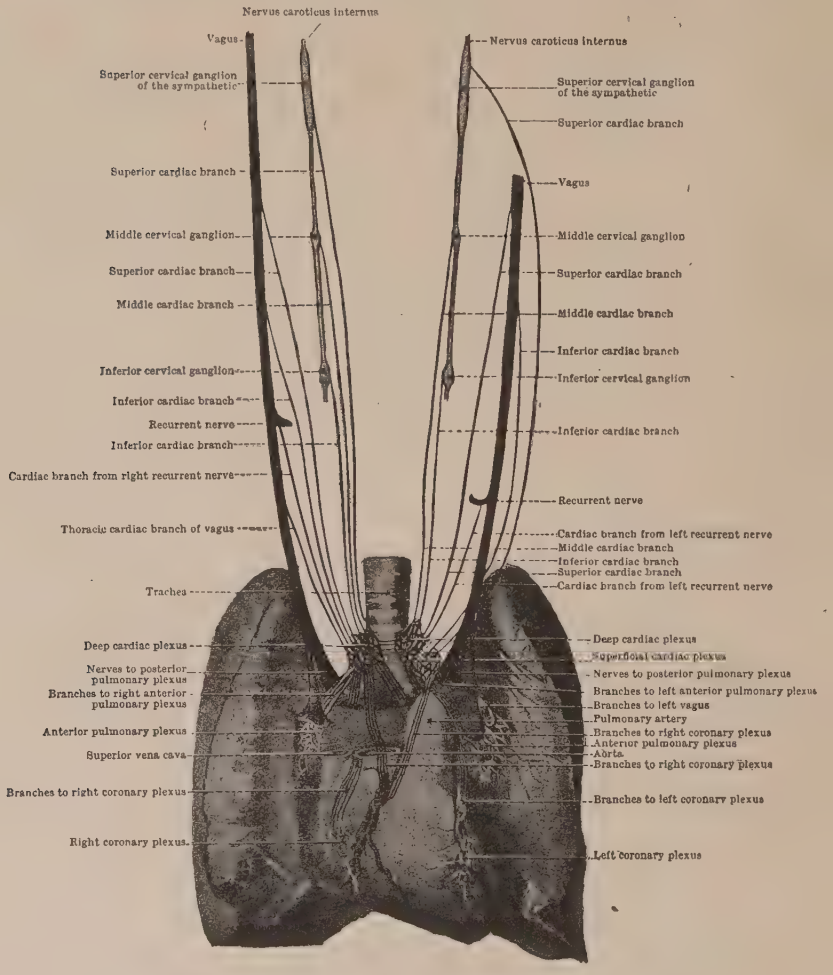


FIG. 62.—The Cardiac Plexuses.

trachea. The nerves contributing to its formation are—**on the right side,** all the cervical branches of the vagus and sympathetic, and the thoracic branches of the vagus

and recurrent laryngeal nerves; **on the left side,** the inferior cervical branch of the sympathetic, the superior cervical branch of the vagus, and the cardiac branches of the left recurrent laryngeal nerve.

The **coronary plexuses** accompany the coronary arteries to the heart. They are right and left. Each is joined by fibres from the superficial cardiac plexus, but the main source of the coronary plexuses is the deep cardiac plexus. Each half of it supplies a plexiform communication to the anterior pulmonary plexus, and then extends down along the pulmonary artery to the heart, to become connected with the coronary arteries, along which the right and left coronary plexuses extend to the heart muscle. There is a partial decussation of nerve fibres in the cardiac plexus, so that each coronary plexus receives fibres from both sides of the coronary plexus, and from the vagus and sympathetic cord on each side.

The Œsophageal Plexus

The vagus nerve of each side proceeds from the posterior pulmonary plexus as a couple of trunks which pass down to the œsophagus, round which they give rise to the œsophageal plexus. This is joined by branches from the great splanchnic nerve and splanchnic ganglion from the thoracic sympathetic cord (Fig. 61).

XI. Spinal Accessory Nerve

The spinal accessory nerve consists of two parts—**accessory to the vagus,** and a **spinal part,** supplied to the trapezius and latissimus dorsi muscles. The accessory part of the nerve arises by a series of filaments from the side of the medulla oblongata (Fig. 48). The spinal part arises from the lateral aspect of the cervical portion of the spinal cord by a series of rootlets, which appear as low down as the sixth cervical nerve (Fig. 63).

The rootlets unite to form a nerve which passes up

within the dura mater, between the ligamenta denticulata and the posterior roots of the spinal nerves, to the foramen magnum.

It joins the accessory portion of the nerve, and they pass as a single trunk through the jugular foramen into the neck, occupying the same sheath as the vagus.

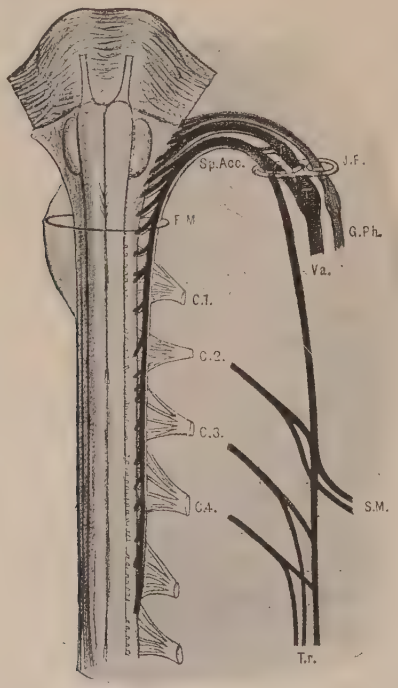


FIG. 63.—Scheme of the Origin, Connections, and Distribution of the Spinal Accessory Nerve.

Sp Acc., Accessory nerve; C.1–4, First four cervical nerves (posterior roots); Va., Vagus nerve; R., Ganglion jugulare; T., Ganglion nodosum; G.Ph., Glossopharyngeal nerve; S.M., Nerves to sternocleido-mastoid; Tr., Nerves to trapezius; F.M., Foramen magnum; J.F., Jugular foramen.

Outside the jugular foramen the **accessory portion** of the nerve separates, and becomes incorporated with the vagus. A few fibres join the ganglion of the root, and the main part of the nerve joins the ganglion of the trunk. Some of the nerve fibres pass over the ganglion and are continued

in the trunk of the vagus as cardio-inhibitory fibres. The fibres which join the vagus are connected with the cells of the ganglion, just as in the case of the ganglia of the sympathetic, and constitute the viscero-motor fibres for the supply of the musculature of the organs contained in the splanchnic area.

The **spinal part** of the nerve, separated off from the accessory portion, passes almost vertically downwards in the side of the neck. It passes over, under, or in rare cases through the internal jugular vein, and is to be found under cover of the anterior border of the sterno-mastoid muscle in its upper third. It here lies close to the under surface of the muscle, accompanied by the sterno-mastoid branch of the occipital artery. Piercing that muscle the nerve crosses the posterior triangle in a line between the junction of the upper and middle thirds of the posterior border of the sterno-mastoid and the middle and lower third of the anterior border of the trapezius muscle. It supplies the two muscles, and communicates with the second, third, and fourth cervical nerves. Beneath the sterno-mastoid it is joined by a branch from the second cervical nerve, which also supplies the muscle. As it crosses the posterior triangle it is joined by branches from the third and fourth cervical nerves, and beneath the trapezius muscle communications again occur with branches of these nerves, which also supply the muscle.

XII. The Hypoglossal Nerve

The hypoglossal nerve arises by numerous filaments from the medulla oblongata between the pyramid and the olive (Fig. 48). These rootlets usually form two nerves which pass through the anterior condyloid foramen or foramina, and combine to form a single trunk (Fig. 49).

In the neck, the nerve takes a curved course, downwards and forwards, to the tongue. It crosses the internal and external carotid arteries, and lies superficial to the lingual

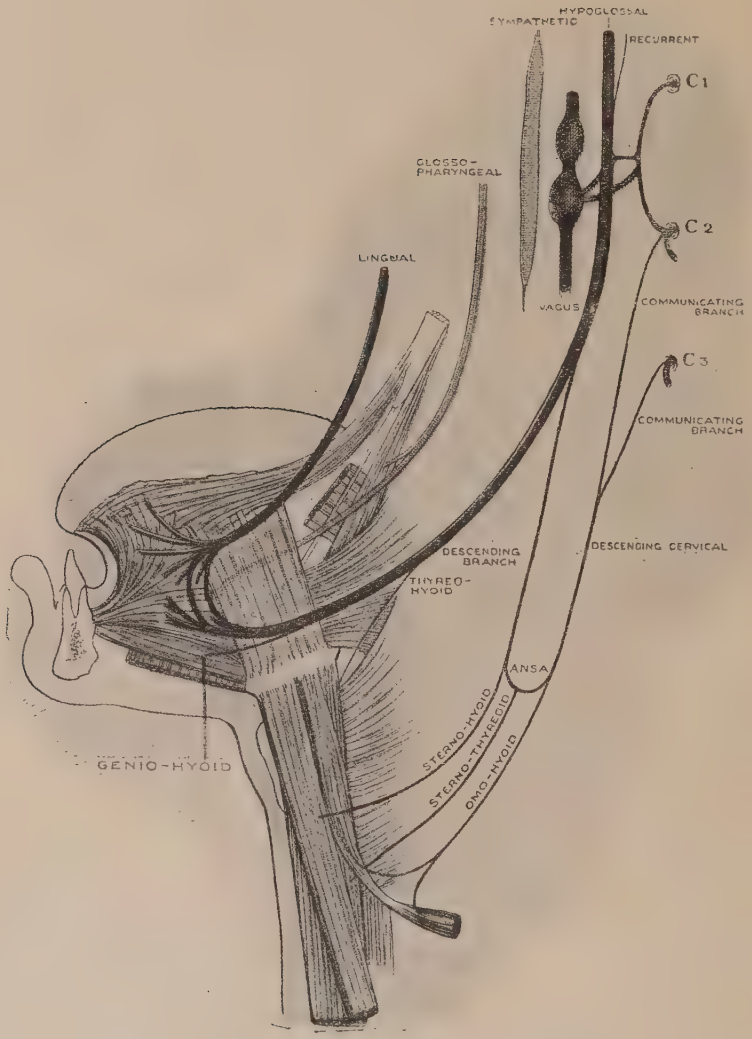


FIG. 64.—The Muscles of the Hyoid Bone and Styloid Process, and the Extrinsic Muscles of the Tongue, with their Nerves.

artery above the great cornu of the hyoid bone. It hooks round the occipital artery in this part of its course. It crosses the floor of the mouth between the mylo-hyoid and

hyoglossus muscles, and ends in the muscles of the tongue.

Branches and Communications. (Fig. 64).—Communications occur with the following nerves: superior cervical sympathetic ganglion, the ganglion of the trunk of the vagus, and the loop formed between the first two cervical nerves. In the floor of the mouth it also forms loops of communication with the lingual nerve.

Branches.—The communicating branch from the loop between the first two cervical nerves is of importance in relation to the distribution of the hypoglossal nerve. The collateral branches are all derived from the first two cervical nerves through this connection.

(1) **Recurrent branch.**—This supplies the dura mater of the posterior fossa of the skull, and is probably derived from the first and second cervical nerves.

(2) **Descendens hypoglossi.**—This is a considerable nerve, derived from the connection with the first and second cervical nerves. It descends in the neck in front of the main arteries, and is joined about the level of the lower border of the cricoid cartilage by the **descendens cervicis** nerve formed by branches (**communicantes hypoglossi**) from the second and third cervical nerves. By their union is formed the hypoglossal loop (**ansa hypoglossi**), from which branches are distributed to both bellies of the omo-hyoid, to the sterno-hyoid, and sterno-thyroid. These muscles are thus innervated by the first three cervical nerves.

(3) The nerve to the **thyro-hyoid** muscle is again a derivative of the connection with the first two cervical nerves. It arises from the hypoglossal nerve before it disappears beneath the mylo-hyoid muscle.

(4) The nerve to the **genio-hyoid** muscle is also regarded as a derivative of the loop between the first two cervical nerves.

(5) **Lingual** branches.—The hypoglossal nerve itself is distributed solely to the muscles of the tongue.

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